University of Alberta

Performance Measurement Using Systems Dynamics in an SME

by

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Abstract

This research provides an evaluation of the use of System Dynamics (SD) to develop a Performance Measuring Framework (PMF) that can be applied in a Small and Medium Sized Enterprise (SME). PMFs in SMEs can provide a base for strategic decision-making to compete in a global environment. SD can provide a way of analyzing the behavior of complex environments to indicate which "key factors" should be controlled for improving operations.

A review in the literature relating the mentioned topics is provided; as well as a case study in which a SD computer simulation model is applied in a SME. The model generated data on the future performance of the business, which was used for a sensitivity analysis. "Key factors" were determined and they were used for goal setting, and to develop a PMF. Further research is suggested on the use of SD for developing a PMF integrating multiple management systems.

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List of Abbreviations

SD = System Dynamics

ST = Systems Thinking

PMF = Performance Measurement Framework

PM = Performance Measurement

SME = Small-to-Medium-Sized Enterprise

Chapter 1 – Introduction

1.1 Background

Business Performance Measurement has been a topic of concern for many academics and researchers in the management area during the past decades. In the late 1970s and 1980s, authors expressed a "general dissatisfaction with traditional accounting-based performance measurement systems" (Bourne et al., 2000). This is because they presented some deficiencies in capturing the dynamics of business performance due to their "single focus view on profitability" (Tangen, 2004).

Many other Performance Measurement Frameworks (PMFs) were developed as alternatives to financial measures, such as the "Balanced Scorecard" (Kaplan and Norton, 1992), the "Triple Bottom Line" (Elkington, 1998) and the "Performance Prism" (Neely and Kennerly, 2002). These PMFs provided a way of "including measures of external success as well as internal performance, and measures which are designed to give an early indication of future business performance" (Bourne et al., 2000).

However, current PMFs still show some deficiencies in providing "support to the associated monitoring and decision-making processes" (Santos et al., 2002) in a company's operational and financial areas. In addition, as "organizations and their environment are becoming more and more complex, decision makers find it more difficult to weight all the factors in a given situation without some explicit, systematic aids" (Waddell and Sohal, 1994).[1]

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[1] More detailed information on PMFs is provided in Chapter 2.

In Small to Medium Sized Enterprises (SMEs), special conditions make decision-making more difficult than in larger enterprises. As O'Reagan et al. (2005) mentioned, SMEs compared to larger companies are

- more resource limited
- "more open and vulnerable to external shocks" such as a downturn in sales, or drastic exchange rate variation
- less likely to be able to afford "to make decisions that pose inherent risks" since a minor mistake can bankrupt a SME.

Since current PMFs have difficulties in representing a complex environment and fail to aid operational and financial decision-making, a new PMF is needed. In addition, for it to be helpful in a SME's decision-making process, a PMF has to overcome resource limitations, protect the company from external shocks, and reduce decision risks. A System Dynamics (SD) perspective can be the answer to overcome this problem, and can be used to develop such a new PMF for a SME.

SD is a methodology introduced in 1961 by Jay Forrester (Forrester, 1961), based on the systems theory, which states that "all natural or human systems are groups of elements that interact with each other and the environment, and have a defined behavior as a whole" (von Bertalanffy, 1968). The theory supporting SD considers that "all systems, no matter how complex, consist of networks of positive and negative feedbacks, and all dynamics arise from the interaction of these loops with one another" (Sterman, 2000).

The main purpose of the methodology is "to enhance learning in complex systems" (Sterman, 2000), in other words, SD "is an approach to understanding and forecasting the dynamic behavior of complex business, social and other systems" (Winch, 1995). This ability to explain the behavior of complex business systems is a reason why SD can be helpful for developing the previously mentioned PMF and aid in decision-making.

In SD theory, "all decisions take place in the context of feedback loops" (Forrester, 1961). If their behaviors are not understood, some decisions can lead the company into "unanticipated reactions" (Sterman, 2000). By learning about a system's complex behavior based on feedback loops, "we can adjust our decisions to align the estate of the system with our goals… and even redesign the system itself" (Sterman, 2000).

In order to help explain complex systems for decision-making, different tools such as computer simulation modeling have been applied to "develop useful, reliable, and effective models to serve as virtual worlds to aid learning and policy design" (Sterman, 2000). Using these simulation models, a system's behavior can be analyzed in order to recognize the "complex set of results for each policy application" (Olson et al., 2005) as well as to "compare alternative policies over a complex set of interacting criteria" (Olson et al., 2005). Thus, SD computer-based modeling and simulation can be a helpful tool for understanding a SME's behavior, analyzing the impact of management decisions in a complex context, and designing a new PMF.

1.2 Justification of the Study

This study continues the research on the topic of PM in a Small-to-Medium-Sized Enterprise by using SD, done by the Auditing and Integration of Management System Lab (AIMS Lab) of the University of Alberta, Canada.

In the previous work (Ali, 2003), a PMF was developed utilizing SD in a small valve manufacturer based in Alberta. A simulation model was created by using the SD software "Stella" to represent the internal behavior of the company's systems or sectors of operation such as the Cash Flow Sector, Ordering Sector, Financial Sector, Machining Sector, Raw Material Sector and the Production Lines Sectors. The data for constructing the model were obtained from a survey completed by the company's manager, and his recollection of four months of financial information. The model was used to perform a sensitivity analysis to see which variables were the possible company drivers that should be measured and used as a basis for the PMF.[2]

The previous study had some opportunities for improvement, some pointed out by the previous researcher and some identified through a review of the previous work:

- "[T]he model incorporates only the price of oil as an external factor affecting the company that was studied. Further quantification of the many relationships affecting the company would need to be examined in order to design a more realistic model for it" (Ali, 2003).
- In the analysis of production operations, certain products were found to have generated considerable variability in time and costs, making the company's behavior difficult to analyze. Thus, it was recommended that products named as "Special Orders" should be considered as a separate system (Ali, 2003).
- Three months of data is a limited amount of information, so a larger amount is needed for the model to be more accurate in representing the company's behavior.
- The study did not present a feedback loop diagramming analysis of the systems' behavior. So, it was not identified which were the reinforcing or balancing cycles.

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[2] Information obtained from Ali (2003).

- The management of the studied company did not provide any feedback on the results of the research, so no evidence suggests that it can be applied to support decision-making.

This study is intended to address these opportunities for improvement. Moreover, this study will provide a new analysis of how this tool can be applied in a SME and will also provide a basis for the development of a generic PMF for a SME.

1.3 Objective of the Study

The objective of the study is to design a new PMF for a manufacturing SME based in the province of Alberta, Canada, by using the SD methodology and computer-based simulation modeling. Such a PMF will be capable of representing the dynamic behavior of the internal and external systems influencing business performance, as well as being a reference for management decision-making.

The expected result is a SD computer-based model of management systems for a manufacturing SME in Alberta. This model will be based on financial measures (the ones that represent a monetary value), but it will also integrate the non-monetary measures of the production system and the sales system, as well as those systems influencing the business performance from the industry sector and the economy.

The computer model will be developed by using Stella, a SD software. In addition, this model will be the basis for a PMF designed as a useful tool to support management decision-making and will be suitable for being easily expanded to integrate new management systems.

The main structure for this computer model will be based on a previous work (Ali, 2003), in which a simulation model was applied to a valves manufacturer. The current research has the purpose of reviewing and improving the results of this previous study by applying it in the same company, but generating a new model for comparison. The new computer model is intended to be able to simulate the company's sales trends over the next 10 years, by using a different variable than the oil price used for projections in the previous work (Ali, 2003). Moreover, this simulation model will include a broader approach in the external factors and will not include only the oil price trends. Therefore, the new model will include industry trends like the oil extraction plants projections as well as economical factors such as the exchange rate CAD-USD. Furthermore, the model's results will be delivered to the company's management so that these results can be used in decision-making and to obtain feedback, which was not provided in the previous research.

1.4 Thesis Organization

In Chapter 2, this thesis will provide an overview of the literature in the fields of SD, PM, Decision-Making, and SMEs. This literature review will provide the background of the topics as well as the conceptual basis for the study's development. The survey will show the relationships among the different fields, as well as the previous work relating them, and will support the achieving of the research objectives.

In Chapter 3, the theoretical basis of the methodology followed in the research will be shown. This chapter will include information on the selection and development of the computer simulation model (including data gathering), as well as how the model can be used to achieve the research's objectives.

In Chapter 4, results will be presented, focusing mainly on those created from the model. The model's sectors and sub-sectors will be described in detail, and the simulated data results will be presented. This chapter will also include the process of validation for the model, including a comparison of past data with those generated by the model, as well as the perceptions of the people involved in the study.

In Chapter 5, a sensitivity analysis will be carried out to modify the conditions of the different variables involved, in order to observe their influence on the system's behavior. Furthermore, this chapter will describe how the new PMF was developed based on the case study.

In Chapter 6, conclusions will be provided based on the analysis, and recommendations will be given. Moreover, the possibilities for the future development of this study will be mentioned.

Chapter 2 - Literature Review

2.1 Introduction

This chapter provides a broad coverage of the literature on the topics of PM and SD, including their relationship with each other and with decision-making and SMEs. This extensive research will include information on previous cases in which more than one of these concepts was studied. Moreover, the conceptual background achieved by this literature survey, will be used to find new ways of interrelating the topics, and to provide the conceptual basis and the research objectives for the present study.

2.2 Performance Measurement

2.2.1 What is PM?

As previously discussed in Chapter 1, the past decades have seen an increasing interest in business PM in the management area. Managers were concerned about using only financial or cost-related measures in order to assess a company's performance (Bourne et al., 2000; Tangen, 2003). Furthermore, new PMFs were needed that would "include a portfolio of measures aimed to balance the more traditional, single focus view on profitability." (Tangen, 2004). But what exactly is "PM" and how can it help management?

Laitinen (2002) defines "performance" as "the ability of an object to produce results in a dimension determined a priori, in relation to a target". In the business context, the object is the company, and the results are its different outputs, such as its products or services, and profits. In order to determine whether the outputs are improving or getting worse, there should be, as Laitinen suggests, a relation with a target. That relation is achievable only if we have a measure of the results and can compare them with the predetermined goal. The difference between the target and the actual results is the measure of performance.

PM is not limited to finding only differences between real and wanted results, another "objective of measurement is… to provide information that helps the organization to take appropriate action with the ultimate goal of improving operations" (Santos et al., 2002). Thus, another definition of PM is "the process of quantifying the efficiency and effectiveness of past action [referring to] the level of performance…of business actions" (Neely, 1998). "Effectiveness" refers to "the extent to which customer requirements are met" and "efficiency" is "a measure of how economically the organization's resources are utilized when providing a given level of customer satisfaction" (Neely, 1998).

These different focuses suggest that a PM system is useful because it:

"enables informed decisions to be made and actions to be taken because it quantifies the efficiency and effectiveness of past actions through the acquisition, collation, sorting, analysis, interpretation and dissemination of appropriate data" (Neely, 1998).

Thus, managers use PM because they are looking for ways to increase their knowledge of "how well their organization is performing, as this helps them to decide what they should do next." (Neely, 1998). However, "effectively measuring and managing organizational performance is a complex and difficult task" (Santos et al., 2002).

For a PM system to be useful, it has to be carefully designed to measure what is really important to the business, because as Neely (1998) comments "measure the wrong things and things will go wrong". A PM system also has to ensure that people have control over what even is being measured, for "one of the fundamental tenets of PM is that it is not fair to measure people on something over which they have no control" (Neely, 1998). Additionally, since measures can influence the behavior of the people involved in the business by sending messages about what matters (Neely and Adams, 2005), they have to be designed to account for the behaviors they will encourage when implemented (Neely, 1998).

A case illustrating how measuring can influence behavior is presented next: during the 1990's, the Levi company created in all of its North American facilities a team-based production system in which all team members worked at different tasks of jeans' manufacturing, with the purpose of reducing the probability of routine work injuries. Once the system was installed, the company wanted to increase productivity and created a series of measures of performance as the basis for rewards. However, these measures were based on team performance. That situation soon created a conflict since the high-skilled workers were not receiving what they should have been because of the low-efficiency workers on their team. People started to pay more attention to what team they were going to join rather than focusing on helping low-efficiency workers to improve and increase overall productivity. Moreover, the high-efficiency workers started to be less productive since they did not link the rewards they were receiving with their individual work (Chase et al., 2004).

Once the appropriate measures are chosen, a company must decide on the benefit of measurement. By itself, measurement can help managers know how their business is performing and to identify opportunities for improvement; however, the true benefit is obtained when an action follows a measurement (Neely, 1998). As a result, the implementation of a PMF, consists, as Bourne et al. (2000) mention, of three phases:

1) "The design of the performance measures": Decide what to measure according to what the company intends to achieve.

2) "The implementation of the performance measures": Start measuring and assess the company's performance.

3) "The use of the performance measures": Identify the company's key drivers and make decisions.

Since every organization has to decide on the appropriate measures, to implement them, and to use that information to make decisions, "performance measurement systems do vary a great deal between one organization and another" (Medori and Steeple; 2000). For this reason, many different PMFs have been created to be applied in different organizations, in order to solve the previously discussed deficiencies of current financial-based performance measures. These PMFs will be described in the next section.

2.2.2 PMFs

2.2.2.1 The Triple Bottom Line

As previously mentioned, current financial-based PM systems have some limitations in assessing the overall performance of a company. As concerns about non-financial performance measures were raised, new frameworks were developed, like the Triple Bottom Line reporting scheme, which "provides information beyond financial results that investors, employees, customers and advocates need to make informed decisions" (GRI, 2002). This framework's main purpose is to integrate financial, environmental as well as social reporting (Marshall and Harry, 2005; GRI, 2002; Elkington, 1999).

The concept of reporting on the three dimensions came from the idea of "sustainability". At first, it was understood as "harmoniz[ing] the traditional financial bottom line with emerging thinking about the environmental bottom line", but later, sustainability was merged with "the element which business has tended to overlook – social justice (Elkington, 1999). Reporting on these three different dimensions this framework provides information that managers can use "to help assess the quality and quantity of a firm's intangible assets, such as reputation, capacity to innovate, quality of management, human capital and environmental assets and liabilities" (GRI, 2002).

Under the Triple Bottom Line scheme, companies must be capable of producing value in the following three different areas:

Economic: This area includes not only monetary measures, but also the Economic Value Added (EVA), which is a measure of whether a company is creating or decreasing value from the overall amount of capital used (Elinkington, 1999).

Environmental: This area involves the Environmental Value Added, defined as "wealth creation and profit with a charge for the natural capital employed" for both renewable and non-renewable resources (Elkington, 1999).

Social: This area involves a business's "impacts on human and social capital". "Human capital" refers to the "knowledge and skills developed or lost". "Social capital" refers to "the levels of resilience, mutuality and trust in communities…" (Elkington, 1999).

In order to "manage a given company's performance effectively, we need to be able to measure it" (Elkington, 1999). Furthermore, in order to assess whether a company is producing "sustainable value", managers must "find accurate, useful and credible indicators of progress in terms of economic prosperity, environmental quality and social justice" (Elkington, 1999). Due to the need to create general indicators for the three different dimensions, the "Global Reporting Initiative" (GRI) was created.

The GRI is an organization jointly founded in 1997 by the Coalition for Environmentally Responsible Economies and the United Nations Environment Programme (UNEP) (GRI, 2002). The GRI's primary purpose is to "disseminate a generally accepted framework for reporting information now absent from conventional corporate financial reports" (GRI, 2002). The GRI provides the world's only framework for measuring and reporting the contribution of different businesses or organizations to the different areas of the Triple Bottom Line (GRI, 2002).

A PMF based on the Triple Bottom Line can provide a method for measuring sustainability. However, this framework cannot satisfy the specific requirements of SMEs for a PMF, because:

1) It reports on an organization at a given point in time, but does not provide a system for how to improve the different indicators.
2) It does not identify the key drivers of a company's performance so that special attention can be given to them.
3) It does not take into account the influence of the external economical variables and the market environment.
4) This framework lacks measurements in the operational area.
5) Other dimensions such as quality are missing, and this framework does not specify how they can be integrated into the framework.

2.2.2.2 The Balanced Scorecard

The Balance Scorecard was developed in the early 1990's by Robert Kaplan, professor of Leadership Development at the Harvard Business School, and David Norton, president of Renaissance Solutions, Inc., a Massachusetts-based consulting firm (Sim and Koh, 2001; Kaplan and Norton, 1996). This framework's main purpose is to provide a "balanced" system for PM that goes beyond traditional financial-based accounting measures (Kaplan and Norton, 1996) and emphasizes "non-financial measures" (Amaratunga et al., 2001).

The Balanced Scorecard includes traditional financial measures representing an organization's past and adds non-financial measures representing the drivers of future performance (Kaplan and Norton, 1996). Balance among financial and non-financial measures is considered as "necessary for efficient and effective movement" and "for assisting in maximizing potential" (Amaratunga et al, 2001).

In the Balanced Scorecard, "objectives and measures… are derived from the organization's vision and strategy" (Kaplan and Norton, 1996). This process is based on the paradigm that considers that "the best performance measures are those linked to a business strategy" (Sim and Koh, 2001) and that "performance measures should be derived form strategy… to reinforce the importance of certain strategic objectives" (Skinner, 1969). However, this point is a questionable because strategies are based on top management's judgment (Amaratunga et al., 2001) and not to fill gaps between desired and actual performance.

As a "top-down process driven by the mission and strategy of the business unit", the Balanced Scorecard considers that measures "must be part of the information system for employees at all levels of the organization" (Kaplan and Norton, 1996). In other words, the top management strategy is transmitted through measurements to all levels of the organization. Moreover, the scorecard should "be seen not only as a record of results achieved. ...[i]t is equally important that it be used to indicate the expected results … and communicate the business plan and thus the mission of the organization" (Amaratunga et al, 2001).

The Balanced Scorecard is not only a collection of measures, but also reports on the "economic and operating performance of an organization" (Amaratunga et al, 2001).

Furthermore, it measures "how business units create value for current and future customer and how they must enhance internal capabilities and the investment in people, systems, and procedures necessary to improve future performance" (Kaplan and Norton, 1996). All these different measures are distributed among the Balanced Scorecard's four different perspectives (1) the customer perspective, (2) the internal business processes perspective, (3) the innovation and learning perspective, and (4) the financial perspective (Kaplan and Norton, 1996). *See Figure 1 for a graphical representation of the four perspectives of the Balanced Scorecard.*

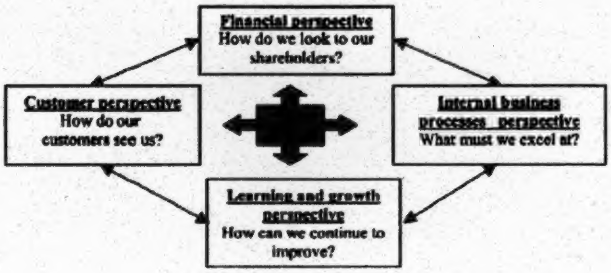
Financial perspective
How do we look to our shareholders?
Customer perspective
How do our customers see us?
Internal business processes perspective
What must we excel at?
Learning and growth perspective
How can we continue to improve?

Figure 1: Four perspectives of the Balanced Scorecard

Source: Amaratunga et al., 2001

From the customer perspective, the Balanced Scorecard assesses whether an organization has the ability "to provide quality goods and services" and also evaluates "the effectiveness of their delivery and overall customer service and satisfaction" (Amaratunga et al, 2001). To measure a company's achievements in these areas, managers should target the market segments on which they want to focus, and set a series of measures for the company's entire operations (Kaplan and Norton, 1996).

The internal business processes perspective provides a way of analyzing an "organization's internal processes… and the mechanism through which performance expectations are achieved" (Amaratunga et al., 2001). This dimension reinforces the customer perspective by translating customer-based measures into what the "organization must do internally to meet its customers' expectations" (Amaratunga et al., 2001). Moreover, this perspective allows managers "to focus on those critical internal operations that enable them to satisfy customer needs… and key processes are monitored to ensure that outcomes will be satisfactory" (Kaplan and Norton, 1992).

The innovation and learning perspective helps managers to identify "the parameters that the organization considers most important for competitive success" (Kaplan and Norton, 1992) in a changing environment. Furthermore, this perspective considers not only "what [a company] must do to maintain and develop the know-how required for understanding and satisfying customer needs, but also how it can sustain the necessary efficiency and productivity of the processes which is presently created for the customer" (Amaratunga et al., 2001).

The fourth perspective involves financial performance measures. From this perspective managers can not only measure different aspects of the financial system, but can also assess "whether the organization's strategy, implementation, and execution are contributing to bottom-line improvement. [The measurement obtained from this perspective show] the results of the strategic choices made in the other perspectives" (Amaratunga et al., 2001). Thus, if managers make fundamental improvements in their operations, "the financial numbers will take care of themselves" (Kaplan and Norton, 1992).

The integration of the four perspectives allows an organization to achieve its expected financial results and also to monitor its "progress in building the capabilities that are necessary for acquiring the ‘intellectual capital’ or ‘intangible assets’ needed for future business growth and for providing keener competition” (Kaplan and Norton, 1992). However, unless the Balanced Scorecard provides “good coverage of the dimensions of performance… [it] does not provide a mechanism for maintaining the relevance of defined measures" (Hudson et al., 2001).

The Balanced Scorecard has many advantages over the traditional financial based measures, but, it still has some deficiencies:

1) It is based on strategies generated by a manager’s judgment, and not on an organization’s actual behavior.
2) Key drivers are identified by past performance and not by looking at the future trends.
3) Measures that become obsolete and lose relevance over time cannot be tracked.
4) It does not provide a way of integrating new dimensions such as environmental issues or safety, into the PM system.
5) This system does not monitor the actions taken based on the performance information.

2.2.2.3 The Performance Prism

The Performance Prism, one of the most recent PMFs, was created by Andy Neely and Mike Kennerly, professors at the Cranfield School of Management, and by Chris Adams, of Andersen Consulting. This framework is “designed to assist PM selection – the vital process of picking the right measures” (Neely et al., 2001). Thus, this framework "can be used by management teams to influence their thinking about what the key questions are that they want to address when seeking to manage their business" (Neely et al., 2001).

The designers of the Performance Prism argue that measures should not be derived from strategy. For "organizations [to] adopt particular strategies… they [have to] believe those strategies will help them achieve a specific, desirable end goal" (Neely and Adams, 2005), which "is to deliver value to some set of stakeholders" (Neely et al., 2001). The concept of "stakeholders" goes beyond a narrow focus on shareholders and is a response to the tendency in the 1980s and 1990s to recognize more stakeholder groups such as customers (Neely and Adams, 2005). Other stakeholders that the Performance Prism considers include suppliers and even the regulatory or legal community (Neely and Adams, 2005). Thus, the Performance Prism is based on the belief that "managers in organizations [should] consider the wants and needs of all of their stakeholders" (Neely and Adams, 2005).

To help in choosing the best measures to encourage an organization to follow a strategy that will satisfy stakeholders, the Performance Prism has five interrelated facets (extracted from Neely et al., 2001) (*See Figure 2 for a diagrammatic representation)*:

1) Stakeholder Satisfaction: This facet involves identifying stakeholders and their needs. "Stakeholders" are not limited to shareholders and customers, as stakeholders were in previous PMFs.
2) Strategies: To define which strategies will be used to satisfy stakeholders needs.
3) Processes: This facet involves identifying which processes will support the strategies to satisfy the stakeholders' needs and determining if these strategies are

working efficiently and effectively. To avoid failure, an organization's processes must be really aligned with its strategies (Neely and Adams, 2005).

4) Capabilities: This facet involves all the resources, such as "people, practices, technology and infrastructure" (Neely and Adams, 2005), that will jointly perform an organization's processes. Thus, this facet allows managers to assess which capabilities are necessary to run the processes.
5) Stakeholder Contribution: This facet enables managers to take into account that stakeholders not only receive value from the organization, but also contribute to it by interacting with it. In other words, this facet can provide "a clear understanding of the 'dynamic tension' that exists between what stakeholders want and need from the organization, and what the organization wants and needs from its stakeholders" (Neely and Adams, 2005). For example, when a company delivers a product to a customer, the customer pays the company, but if the product does not satisfy the customer's expectations, the customer will complain.

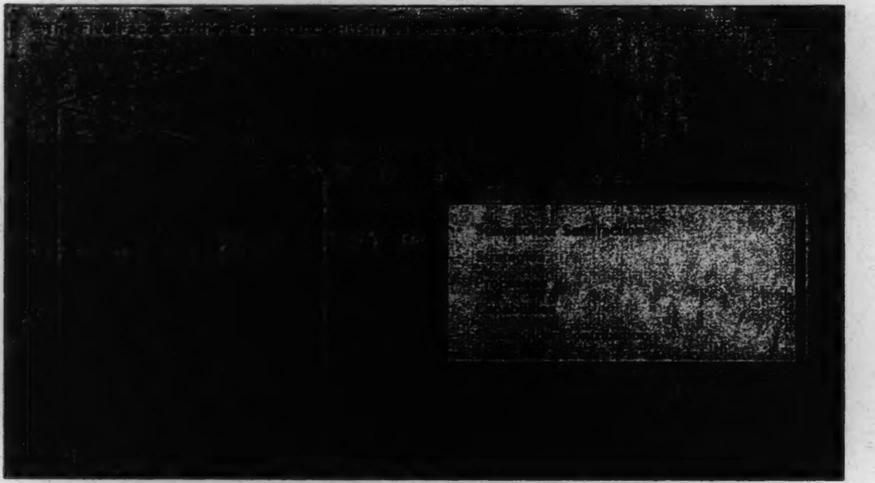

Figure 2: The Facets of the Performance Prism

Source: Neely and Adams, 2005

The Performance Prism goes beyond its five facets and encourages "managers to think through the links between measures in a way that other frameworks do not intuitively suggest" (Neely et al., 2001). This encouragement supports to the concept that "performance is not uni-dimensional. To understand it in its entirety, it is essential to view it from the multiple and interlinked perspectives" (Neely and Adams, 2005).

The data obtained from measurements by using the Performance Prism "will never replace executive intuition, but [they] can be used to greatly enhance the making of judgments and decisions" (Neely and Adams, 2005). Moreover, this framework provides a broader look than other frameworks allow at the interaction of a business with its environment, as represented by the stakeholders.

Although the Performance Prism is a more comprehensive framework than the ones previously discussed, it still has some disadvantages:

1) When choosing measurements, it does not account for the complex behavior of the different systems involved. Thus, this framework is limited to managerial judgments and is unable to identify an organization's key drivers by observing the behavior of the different variables involved.
2) It does not provide a way of monitoring the actions taken based on the measurement information.
3) It does not consider the obsolescence of measures over time.

2.2.3 Disadvantages of current PMFs

Neely (1998) has identified the current measurement systems' main problems:

"- An excessive focus on operational and financial measures

- A tendency to measure too much

- A lack of integration between measures and strategy"

Furthermore, "as soon as performance measures are used as a means of control, the people being measured begin to manage the measures rather than performance" because reward is linked to "returning good figures", and people are "motivated to take decisions and pursue courses of action that will make the figures look good, even if this means jeopardizing the performance of the business as a whole" (Neely, 1998).

The current PMFs also do not include a loop for control including corrective action and lack "an integrative framework and suitable platforms to facilitate closed loop control" (Bititci, et al., 2000).

As well, all the analyzed PMFs fail to identify the "relative importance of measures and the problems of identifying true drivers" (Bierbusse and Siesfield, 1997; Schneiderman, 1999). Additionally, a large number of measures dilute the overall impact of measurement (Bierbusse and Siesfield, 1997).

2.3 Decision-Making and PM

PMFs are intended to provide information on a company's performance so that management can make any necessary improvements. Like any other information available for management, the information from PMFs "is used in strategic decision-making to reduce uncertainty" (Frishammar, 2003). However, current PMFs have problems in supporting decision-making in the different contexts that are discussed next.

As organizations and their external environments are "becoming more and more complex, decision makers find it more difficult to weigh all the factors in a given situation without some explicit, systematic aids" (Waddell and Sohal, 1994). Current PMFs fail to aid in this task since they have a tendency to measure too much (Neely, 1999), and a large number of measures "dilute the overall impact" of measurement (Bierbusse and Siesfield, 1997). As well, PMFs also fail to represent the complex behavior of business systems.

Decision-making can be most effective if priorities are defined by periodical formal planning by analyzing possibilities for improvement (Rusjan, 2005). These possible improvements are intended, to have a "competitive impact" and "to guarantee appropriate coordination among business functions, and to guarantee that improvements are coordinated with changes in the environment" (Rusjan, 2005). However, the current PMFs fail to identify "true drivers" and also cannot help managers to understand their company's interaction with its environment.

Moreover, the current PMFs are based on past data and do not forecast future developments. This problem is serious, for "forecasts are an essential part of efficient and effective management; they are a crucial modeling tool both in strategic and tactical decision making"(Waddell and Sohal, 1994). For a forecast to be useful, it has to be applied in the planning stage "to help in making good decisions about the most attractive alternatives for the organization" (Waddell and Sohal, 1994). Furthermore, a forecast used to take an action "may need to be adjusted to reflect the impact of that action" (Waddell and Sohal, 1994).

Due to all the current PMFs' limitations, a new approach is needed. One new approach is use ST theory and SD methodology, which can provide a way to understand and forecast "the dynamic behavior of complex business...systems through a process of 'mapping' the structure of the system and then simulating its behavior over time with an explicit computer-based quantitative model" (Winch, 1995). More detailed information on this topic will be provided in section 2.5.

2.4 SME's and PM

When using PMFs, measures need to be set to assess a company's performance in order to make decisions. Those measures are supposed to be defined on the basis of strategies and/or the requirements of different stakeholders. However, applying the current PMFs in SMEs can be challenging since businesses of this kind have special characteristics that differentiating them from larger ones. "SMEs are not smaller versions of larger firms. Their needs and often their decision-making processes differ significantly from those of larger firms" (Shrader et al., 1989). These differences and their effect on a PMF's ability to aid decision-making are discussed in this section.

First, specific criteria are used to classify an enterprise as SME. The size classification of a business can be determined by the monetary value of annual sales, the annual net revenue, the size of its assets, or the number of its employees (Industry Canada, 2006). A simple method of classification is to identify the size of a company according to the number of employees. If a business has less than a 100 employees, it can be considered as "small", and businesses with between 100 and 500 employees can be considered "medium sized" (Industry Canada, 2006). Thus, in this present study, the term "SME" will mean every business with less than 500 employees.

Hudson et al. (2001) have identified the main differences between SMEs and larger firms:

- A single person manages the company and usually does not delegate.
- Resources are limited in areas such as management, manpower, and finances.
- The market and the number of customers are limited.
- The flat organizational structure provides flexibility.
- An SME has a high potential for innovation.
- Managers tend to be reactive in problem resolution
- Strategy setting is informal and changes frequently.

In one study of SMEs, Hudson et al. (2001), Found that the only common set of measures were usually financial. Moreover, "none of the companies attempted to measure flexibility, and while three of the companies had human resource measures, these were very rudimentary and only covered, for example, staff turnover" (Hudson et al., 2001). Thus, in order for a PMF to be set up in a SME, the PMF has to be first based on financial information, and then a new set of measures need to be defined and implemented.

Another factor affecting the implementation of a PMF in SMEs is that they have a relatively small number of workers and a flatter structure than large businesses, so that "employees often have a greater number of job roles and more responsibility" (Hudson et al., 2001). Therefore, the employees do not have time to thoroughly plan a strategy and make decisions according to it. Thus, "given the resource and time constraints imposed on SMEs, performance measures should be clearly defined, have an explicit purpose, be relevant and easy to maintain and be simple to understand and use" (Hudson et al., 2001).

As well, due to the time constraint and reactive problem solving, PM in a SME "must be very resource-effective and produce notable short-term, as well as long-term benefits, to help maintain the momentum and enthusiasm of the development team" (Hudson et al., 2001). Furthermore, since strategies are informal and change frequently, measures of performance "must be dynamic and flexible enough to accommodate the strategic changes which are a feature of emergent strategies" (Hudson et al., 2001).

In the decision-making context, one of the main differences between SMEs and larger firms is that SMEs do not take large risks due to their "limited resource base" (O'Reagan et al., 2005). For example, a small restaurant opening a new branch might be doubling its capacity, and increasing its current expenses by 100%. Such a restaurant would need an investment to double its assets, if the new branch is not successful, the restaurant might go bankrupt very easily. Therefore, a PMF for a SME must forecast future performance to reduce the level of risk when making decisions.

As well, "the typical markets that [SMEs] serve are often poorly defined with a lack of published data" (Mosey et al., 2002). Moreover, "most SME research focuses on factors that contribute to their survival such as financing, rather than a greater understanding of the growth process and the achievement of sustainable competitive advantage" (Storey, 1994). Thus, such a PMF for decision-making in a SME must be designed on an informed basis. Such a PMF should provide a view of the environmental influences on the company's performance.

A PMF for decision-making in a SME must be dynamic, flexible, concise, clear, and easy to maintain. This kind of PMF can be based on the financial information, but must also take into account the external influences. Moreover, it must be able to forecast future performance in order to reduce risk. In this study, it is proposed that all these needs can be satisfied by developing a PMF by using ST theory and SD methodology. These topics are discussed in the next section.

2.5 Systems Thinking and SD Methodology

2.5.1 ST Background

Ludwig von Bertalanffy created the ST concept in the 1960's in an attempt to integrate different science disciplines for a more "holistic" view of the entire biosphere (Mulej et al., 2004). Bertalanffy developed the "General Theory of Systems" which deals with generalities rather than specific concepts or fields of studies (Mulej et al., 2004). Thus, ST "is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static 'snapshots'" (Frank, 2002). As well, ST joins the traditional cause-and-effect relations of actions, to better explain the entire flow of events representing the complex behavior of the systems we live in (Jambekar, 1995).

In the business context, as "system" can be thought of as a company itself, and the system's components are the internal operational and management activities, and the relations; the interactions within the organization and with the external environment. Thus, ST in business can be used to develop an "ability to view interdependency among various elements of the system and [to locate] leverage points to influence future actions" (Jambekar, 1995).

According to Cusins (1994), five factors provide the basis for ST theory:

1) An arbitrary boundary is what delimitates a system from its environment.
2) The environment provides inputs that cross the boundaries to the system.
3) Inside the system, transformation processes use the inputs.
4) Inputs after being transformed go out of the system as outputs.
5) "The direction of flow indicates the flow of energy, materials, information, etc"

From these factors, Cusings (1994) derives the following implications:

- Systems are always sub-systems of a larger one and at the same time contain within their own sub-systems.
- An environment is a set of systems forming a complex structure.
- A focus system is the one that is within a boundary which is under our attention.
- The outputs of a system are inputs to another and vice versa.

Analyzing the feedbacks which create loops of interaction between systems is a way to understand the structure and behavior of systems. However, understanding a system's behavior is difficult since as the number of subsystems within a system increase, the interrelations among its elements also increase and create a dynamic complexity (Frank, 2002). SD methodology, which will be described next, is used to analyze a system's complex behavior.

2.5.2 SD Background

2.5.2.1 What is SD?

SD is a methodology whose main objective is to increase understanding of the behavior of complex systems. It is a tool for trying to see the big picture, and "seeing the system often allows you to influence how it works" (Senge, 1990). A system's structure, consisting of stocks and flows, nonlinearities, and the resulting feedback loops obtained from the interaction of these elements, determines the system's behavior (Sterman, 2000). These feedback loops also interact with each other, forming an "interlocking structure of feedback loops" (Forrester, 1969).

According to SD theory, intuition in the context of the traditional cause and effect thinking allows us to "infer the dynamics of isolated loops… but when multiple loops interact, it is not easy to determine what the dynamics will be" (Sterman, 2000). The knowledge that "all decisions take place in the context of feedback loops" (Forrester, 1961) enable us to take actions that will produce unanticipated reactions in a system due to "stocks and nonlinearities" (Sterman, 2000).

Since "natural and human systems have high levels of dynamic complexity" (Sterman, 2000), in order to take an action in this context, the behavior of the whole system must be observed and the interaction of the different feedback loops must be understood.

Furthermore, after the systems' dynamics have been understood "the policies, systems and procedures that control short-term actions should assist in converting vicious cycles into virtuous reinforcing cycles" (Jambekar, 2000). Thus, these feedback loops, their behavior by themselves, and their interactions with each other must be analyzed.

Feedback loops represent "interrelationships rather than linear cause-effect chains", and "nothing is ever influenced in just one direction" (Senge, 1990). Furthermore, these feedbacks "show how actions can reinforce or counteract (balance) each other" (Senge, 1990).

2.5.2.2 Feedback Loops Diagramming

To explain the behavior of feedback loops, special ways of diagramming have been created such as causal loop diagramming. Jamberkar (2000) explains, "Causal loop diagrams offer compact and precise representations of interdependencies and are useful in displaying the feedback structure of systems".

These diagrams use arrows to illustrate variables' causal influences (Sterman, 2000), and also use a positive or negative sign to show the kind of relation that each factor has with the others. A positive sign means a direct relation: "if the cause increases, the effect increases about what it would otherwise have been, and if the cause decreases, the effect decreases below what it would otherwise have been"(Sterman, 2000). A negative sign means an opposite relation: "if the cause increases, the effect decreases below what it would otherwise have been, and if the cause decreases, the effect increases above what it would otherwise have been" (Sterman, 2000). Furthermore, the letter "R" or "B", circled by an arrow, is used to represent a positive or reinforcing ("R") loop or negative or balancing ("B") loop, respectively. *See figure 3 for one example of a Causal Loop diagram.*

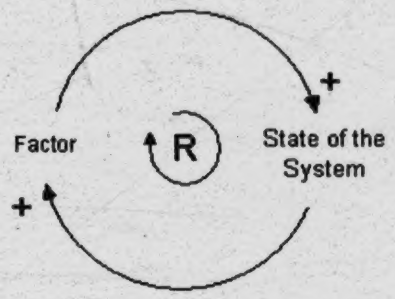

Figure 3.- Causal Loop diagramming example.

Source: Sterman (2000).

Causal loop diagrams are useful to "communicate the central feedback structure of your dynamic hypothesis" and to show "interdependencies and feedback processes (Sterman, 2000). However, these diagrams have the important limitation of being unable to "capture the stock and flow structure of systems, which "along with feedback, are the two central concepts of dynamic systems theory" (Sterman, 2000). For this reason, another type of diagramming, "stocks and flows diagramming", is needed to better illustrate the structure of causal loops.

Stocks and flows diagramming was developed by Forrester (1961), who took the idea from a hydraulic system, which has water flows in tubes coming out of tanks and controlled by valves. Thus, system dynamics are represented by stocks and flows, and their relationship with independent or static variables. This type of diagramming is commonly used in SD software.

Stocks represent an accumulation, or the "state of the system" (Sterman, 2000). They create a delay "between the inflow and the outflow", which generates a "disequilibrium" in the system (Sterman, 2000). The inflows and outflows are simply controlled by internal or external conditions, and the difference between them is the "net flow into the stock" or "the rate of change of the stock" (Sterman, 2000).

Stocks can be of different types, the most common ones being the "containers" and the "conveyors." The first one refers to a simple accumulation in, for example, a water tank that is filled and drained. The second one refers to a delay between the total inflow and the total outflow, for example, the delay that occurs when a piece of material is transported from the storage room to the production line.

Stocks and flows diagrams have a special notation to represent the different elements involved. Stocks are represented as rectangles, and inflow and outflow by pipes pointing into or out from the stock. Flow controls are represented as valves, and variables' interrelations as arrows (Sterman, 2000). A special symbol, the cloud, "represents the sources and sinks for the flow" (Sterman, 2000). Clouds are used to show the boundaries of the representation of reality and are considered to have an "infinite capacity" for "never constraining the flows they support" (Sterman, 2000). *See Figure 4 for an example of a Stocks and Flows diagram.*

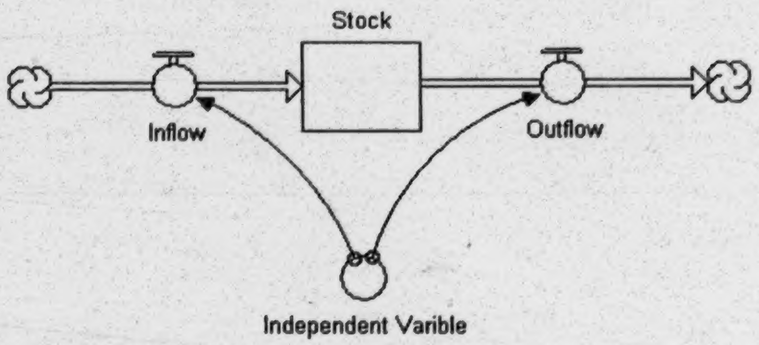

Figure 4.- Stocks and Flows diagramming example.

2.5.2.3 Application of SD in the Business Context

Thurbly and Chang (1995) identify the following benefits of using SD in the business context:

1) SD analyzes not only a company's processes, but also its policies.
2) SD applies the ST approach to study and entire business system rather than studying only the problematic processes.
3) Along with a PMF, a SD helps in establishing metrics and quantifying for business control.

All the benefits of using SD derive from its ability to change our mental models of the behavior of systems. Systems are becoming more and more complex, increasing the difficulty of mentally modeling their behavior, so the concept of using "microworlds" to analyze a predetermined number of variables to evaluate their behavior as a whole was created. De Geus (1997) explains that "creating, revising, and playing in microworlds helps to deepen our knowledge of how the systems we live in work and fail".

Furthermore, "these new microworlds' models allow groups to make explicit, reflect on, test, and improve the mental frames" (Woodside, 2006).

Senge (1990) lists the following benefits of using microworlds:

1) They can be used for "surfacing hidden assumptions, especially those lying behind key policies and strategies, discovering their inconsistency and incompleteness, and developing new, more systemic hypotheses for improving the real system",

2) They can be used to slow down or speed up the behavior of actions to see "long-term consequences of decisions",

3) Space can be compressed in order to allow managers to observe the "consequences of actions that occur in distant parts of the system from where actions are taken".

4) Variables can be isolated in a controlled environment and manipulated to allow for playing with "What ifs?",

5) They can be used to test "new policies, strategies, and learning skills".

In the analysis of microworlds, figuring out the behavior of a very complex system just by simple thought can be difficult. Thus, computer simulation is useful for this kind of analysis. As Sterman (2000) stated, "when intuition fails, we usually turn to computer simulation to deduce the behavior of our models". Thus, different specialized computer programs can be used to simulate microworlds in order to better understand their behavior. Further details on this topic will be given in Chapter 3.

2.6 Opportunities for using SD in PM

In the previous sections, it was mentioned that current PMFs fail to support all aspects of decision-making, for a large number of measures makes these PMFs difficult to use, and the actions taken are diluted, having less impact. As well, these PMFs do not adequately represent the complex behavior of business systems and do not identify a company's true behavior. Moreover, current PMFs are unable to forecast a company's future since they are based only on past data.

Given these requirements for a PMF for decision-making in a SME, the use of SD methodology, which is based on the ST, is proposed. Santos et al. (2002) suggest that using SD in PM can make it "more efficient and effective", "by increasing the information processing capabilities of the decision makers and by enabling them to do more through problem analysis than would be possible without [SD's] use". However, how can SD help to develop a new PMF that can solve the deficiencies identified?

As Santos et al. (2002) state, "only through the development and use of SD simulation models can managers fully understand the implications of non-linearity, feedback and delay among the performance measures and be able to identify the highest leverage points in the system". Thus, SD not only helps to explain the dynamic behavior of a business, it can also be useful to identify the "true drivers" and set indicators based on them. Furthermore, a "sensitivity analysis can be carried out to analyze how robust these indicators are to changes in the priorities and values of the different stakeholders" (Santos et al., 2002).

Moreover, as Bititci, et al. (2000) suggest, the "external and internal environment of an organization is not static but is constantly changing". SD can also help to simulate an organization's environment so that its influences on the company can be measured, and the influences that are "drivers" of the organization can be identified.

Once a company's drivers have been defined and performance measures have been set based on them, actions for performance improvement must be taken. In this context, "SD simulation modeling may play a vital role in testing and comparing alternative actions to improve a system's performance" (Santos et al., 2002). Moreover, before a policy is set to improve operations, it can be evaluated by obtaining a set of complex results by using the SD simulation (Olson et al., 2005).

SD can be helpful in developing a new PMF for decision-making and in compensating for the deficiencies in the older PMFs. An IT platform can be used to design such a PMF, since "maintenance of the information contained within the systems becomes much simpler" (Bititci et al., 2000). As well, the PMF for a SME has to be designed to overcome the limited information available (limited usually to financial measures) and to be easily expanded with new information about a business's performance. Based on all the information analyzed, the problem to be solved in the study can be defined.

2.7 Problem Definition

Current PMFs fail to support decision-making in a SME, since they are not concise and try to manage a large number of measures. Their complexity makes them difficult to maintain, inflexible, unclear, and dilutes the impact of the actions taken. As well, current PMFs fail to represent the complex behavior of business systems, for these PMFs are unable to forecast a business's future behavior and to identify "true drivers." Furthermore, the current PMFs require a large amount of past data, which are especially hard to find in a SME.

To solve this problem, it is suggested that SD methodology be used with the aid of computer simulation model. Thus, this study's goals can be defined as the following:

- Deliver a SD computer simulation model of a SME's behavior, including the internal and external factors influencing the business performance. Moreover, the model must be easy to expand to integrate different management systems, i.e., the Quality Management System, by providing direct links between internal variables and external sectors, which will be able to be used by new sectors.
- Provide a sensitivity analysis and a forecast that will help in decision-making to the management of the company, and identify the "true drivers". This analyzed material will be provided through the simulation of different scenarios and by manipulating different variables. For example, the price can be manipulated to be higher or lower to determine how the changes affect revenue.
- Show that SD can help in developing a new PMF for a SME and can eliminate the deficiencies detected in the current PMFs.

Since this study will continue a previous work on the same topic (See Ali, 2003), the specific goals are the following:

- The new computer model will be able to simulate the company's sales trends for at least over the next 10 years and to include more variables as external factors, including trends in the economy and the industry, and will not include only the oil price trends.

- The new developed computer model will be based on 2 years of financial information instead of 3 months as in the previous work (Ali, 2003).
- The model's results will be delivered to the management of the company so that they can be used in decision-making and to obtain feedback, which was not provided in the previous research.

Chapter 3 – Methodology and Development of the Study

3.1 Introduction

As the purpose of this study is to apply SD principles and techniques to develop a PMF for decision-making in a SME, a methodology must be chosen and developed. It was previously suggested in Chapter 2 that SD could be applied by developing "microworlds" and using computer simulation modeling in order to solve the problems found in current PMFs when applied in a SME. Thus, the methodology to be followed had to consider the use of SD modeling to demonstrate its effectiveness in developing a PMF for a SME.

In this chapter, the methodology chosen will be discussed and how this methodology was applied in a SME to develop a SD theoretical model that was the base for the computer simulation model will be explained. This discussion includes a description of the data-gathering approach, the development of the theoretical model by using SD diagramming techniques, and the transformation of this model into a simulation model.

3.2 Methodology of the Study

In the literature, the methodology proposed by Roberts (1978) best fits the purpose of this study. This methodology was designed for SD modeling and consists of six steps:

1) Problem definition and goal setting.
2) Description of the analyzed system (the company), by using causal loop diagramming.

3) Constructing the quantitative structure of the simulation model by using of stock and flow diagrams (also called Forrester's diagramming), and mathematical representation of interactions. At this point, computer software can be used.
4) Data gathering in order to fill the model. These data can be obtained from the company's historical records or by interviewing experts such as executives or planners.
5) Model Validation, which can be done by using experts' feedback, by comparing the model results with real data, and by testing with random numbers, among other methods.
6) Model use for achieving the previously defined goals of supporting a PMF.

Once this methodology was chosen, it was adapted to this study. The development of its application is explained in the next sections.

3.3 Study development

The first step was to define the problem and set goals. The problem definition and goal setting have been already discussed in Section 2.7 of Chapter 2. Thus, this discussion can proceed to the next step of the methodology: describing the company (the system) by using causal loops diagrams. For this purpose, the characteristics of the company chosen and the reasons for selecting it for this study will be explained.

3.3.1 Company chosen for the study.

The company chosen was the same valves manufacturer studied in a previous work (Ali, 2003). This 16-year-old company is based in Edmonton, Canada. Since it has only 14 employees, it falls into the category of SMEs. Its operations consist of a production line that supplies a distribution network which supplies mainly the oil and petrochemical industry in Alberta and some other industries across Canada and the U.S.

The company's core business is to manufacture standardized industrial valves such as ANSI 150, ANSI 300 and ANSI 600 ("ANSI" stands for "American National Standards Institute", and the number represents the valves' classification based on the pressure they can resist). As well, this company produces non-standard valves that have special add-ons and are available in different sizes.

The company shares some characteristics with regular SMEs (as described in Chapter 2) in addition to the small number of employees:

1) It has limited resources, i.e., limited access to credit and a small client base.
2) The general manager makes all decisions on the company's future.
3) Information on the company's performance is lacking and is limited mainly to financial measures.
4) Limited research is available on the company's field because the company serves a small market.

Because of the characteristics listed above, the company was chosen for Ali's (2002) study and continues to be a good basis for this new study. Moreover, during this researcher's first interview with the manager, he expressed his willingness to help in the development of the study, for he provided information and accepted the agenda for future meetings. The literature considers this type of helpful management attitude to be an important issue when developing a SD simulation model (Turner et al., 2005; Sterman, 2000).

This discussion of second step of the methodology will be completed by describing the enterprise (the system) by using causal loop diagramming. This will become the basis for the computer simulation model. Further details on the company will be given in this chapter when the model's development is explained.

3.3.2 Causal loop model creation

In order to support the simulation model being designed, data were gathered within and outside the company to aid in every stage of the model's development. These data were used to analyze the company's operations and to design each part of the model. Data gathering and causal loop model build-up during this study were performed in three stages: (1) Basic model creation (internal operation of the company), (2) External influences model design, and (3) Integration of internal and external models.

In the basic model creation stage, the first set of data was compiled. Standard financial statement variables were consulted from specialized books in order to support the creation of the first design. (See Flynn, 2001 for references on financial statements.) Moreover, the previous work on this company, in which a simulation model was developed, was consulted, (See Ali, 2003, for more references.) Furthermore, one survey

(*See Appendix 1 for the complete survey*) was completed by the manager of the company to provide information on the organization's basic working structure.

The survey confirms that this company lacked data on measures other than those for financial matters. Thus, it was decided to use the financial variables as the main part of the simulation model. In addition, some ordering and production data obtained from the survey were included as well.

The financial variables detected in the historical accounting information were Cash, Receivables, Payables, Dividends, Retained Earnings, Net Income, Salaries, Price and Total Revenue. The survey showed that the data that could be calculated based on the financial information and other isolated sets of data available in the company were Production Cost, Raw Material Cost, Orders (from clients), Price, Awaiting Orders, Orders to Suppliers, Production, Unmet Orders, Finished Products and Scrap. *See Table 1 for an explanation of each of the financial and non-financial variables.*

The company's overall behavior can be described as the interaction of the internal systems with external factors (*see Figure5 for representation of the overall system*).

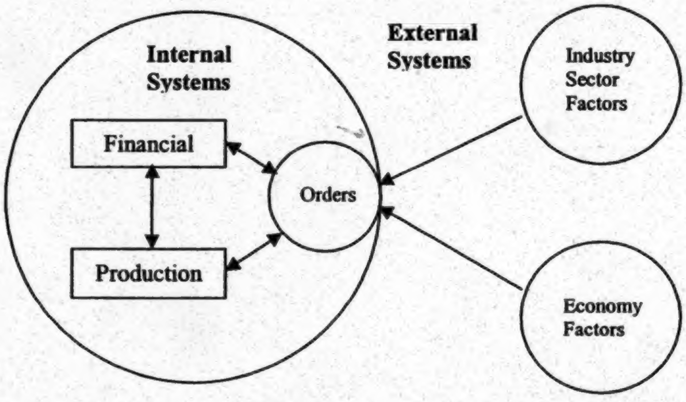

Figure 5 .- Representation of the company's overall system.

Variables	Explanation	Variables	Explanation
Cash	Amount of cash available at a certain moment in time	Overhead Cost	Administration cost as % of overall costs
Payables	Debt generated by the difference between the time supplies are received and the time they are paid for	Orders	Total amount of orders received from clients including every type of product
Receivables	Expected payments from clients.	Awaiting Orders	Number of orders waiting to be completed
Dividends	Amount of money paid to shareholders from income	Production	The action of manufacturing products
Retained Earnings	Amount of cash that is preserved in the company from the net income and is reinvested.	Finished Products	A completed order of a unit of product
Total Revenue	Income due to the sale of products.	Met orders	Orders delivered on time to the clients
Net Income	Total revenue minus the costs involved	Unmet Orders	Orders not delivered on time to clients
Salaries	Amount of money paid to the workers	Production Capacity	Amount of products that can be manufactured per month
Price	Selling Price of the products	Number of workers	Total number of workers in the company
Raw Material Cost	The cost of the materials used to produce the final products	Productivity	Number of products made per worker each month
Machining Cost	Cost of processing the products by using machines	Scrap	Percentage of finished products that are defective and must be scraped
Inventory	Amount of complete sets of parts available to make units of product	Supplier Capacity	Maximum number of units of supply that the major supplier can handle at a time
Orders to suppliers	Order of unit of supplies to make units of products	Cash Availability Factor	Factor defining if enough cash is available to pay for an order to a supplier
Reorder Point	Inventory level at which a new materials order is done		

Table 1: Explanation of variables

The interaction between the internal and external factors occurs through the orders sub-systems, which deals with the orders received from clients. The external factors will be the Industry factors, which include the market trends, and the Economy factors, which include the economic environment.

From the information presented previously, causal loop diagrams were constructed to explain the company's behavior (*see Chapter 2 for an explanation on causal loops*). The first two causal loops diagrams are of the internal systems: the financial system, and the ordering and production sub-systems in the second. *In Figures 6 and 7, respectively.* The third causal loop diagram (*Figure 8*) presents the integration of the previous causal loops to represent all the internal systems.

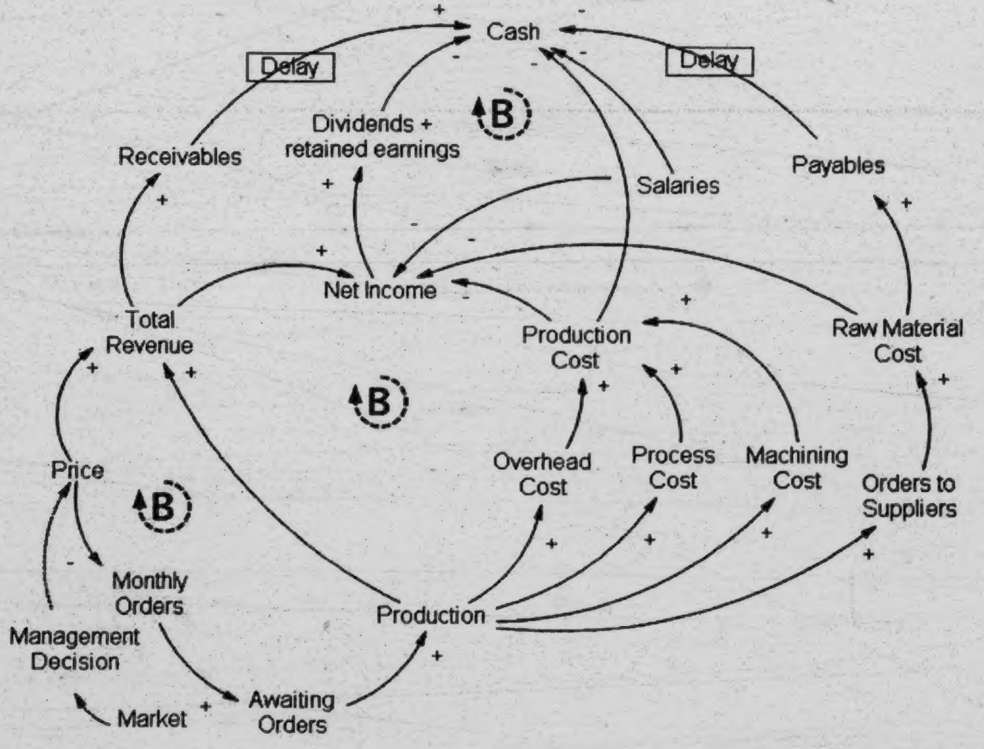
Cash
Delay
Delay
Dividends + retained earnings
B
Receivables
Salaries
Payables
Net Income
Total Revenue
Production Cost
Raw Material Cost
B
Price
B
Overhead Cost
Process Cost
Machining Cost
Orders to Suppliers
Monthly Orders
Management Decision
Production
Market
Awaiting Orders
+
-
+
-

Figure 6.- Causal Loop Diagram of Financial System

Figure 6 shows that

- Cash is increased by receivables and is depleted by dividends paid, retained earnings invested, salaries payments, the production cost, and payables[3]. This process generates the balanced behavior of the financial system. A delay of approximately 45 to 60 days occurs in payments for receivables, and a delay of 30 days for payables. These delays generate an oscillating behavior for cash, which is diminished by payables and then increased by receivables.
- Net income depends on the total revenue minus the production costs, salaries and raw material cost. Production costs include the overhead cost, process cost, and the machining cost. All these cost are generated during production, when the system's behavior again stabilizes.
- The higher a product's price, the more revenue can be generated, but fewer orders will be received. Thus, at a first glance, raising the price does not provide a huge benefit, since a balancing loop occurs. Therefore, this behavior must be analyzed when simulating data by using SD software, to identify in which scenarios the price could be appropriately changed.
- Production depends on the existence of awaiting orders, and these depend on the existence of new orders. This behavior is represented in detail in the orders and production system diagram. This diagram is based on monthly orders, since the financial information on which this study is based is recorded monthly.

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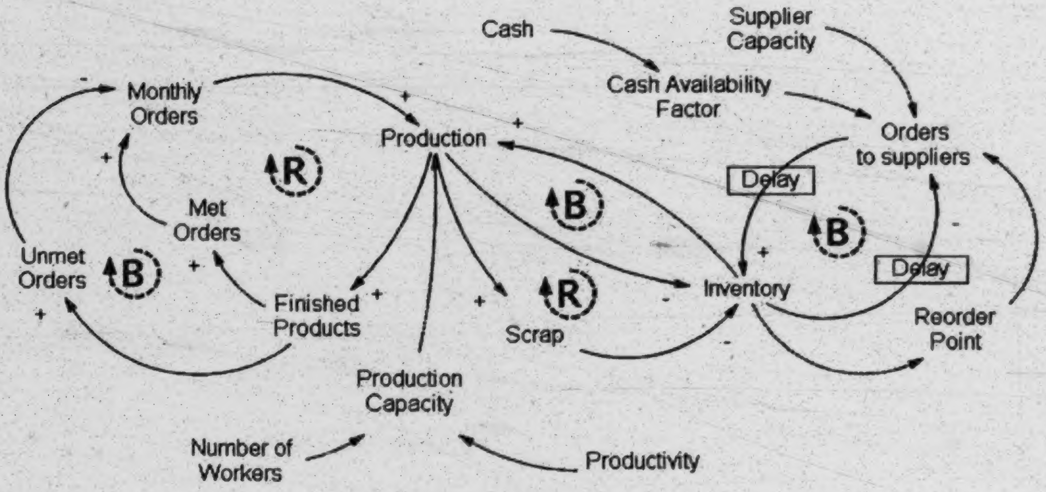
[3] In causal loop diagramming, the direction of the arrow shows the influence of one variable on another and does not show the flow involved in the process. This problem is the main weakness of this type of diagramming, and is one of the reasons why "Stocks and Flows" diagramming is preferred in SD simulation software.

- The price is changed only by management, for whom the main factor is the market conditions.



Cash
Supplier Capacity
Cash Availability Factor
Monthly Orders
Production
Orders to suppliers
Delay
Met Orders
R
B
Unmet Orders
B
Finished Products
Scrap
R
Inventory
Delay
Reorder Point
Production Capacity
Number of Workers
Productivity
+
-

Figure 7.- Orders and Production System

Figure 7 reveals that:

- Production depends on both the orders generated and the availability of inventory. With more inventory, more production can be generated, but as more production occurs, the inventory decreases. This situation creates a balancing loop.
- Inventory is also depleted by scrap; thus, more production must be generated, which generates more scrap, which creates more inventory depletion. This process generates a reinforcing loop.
- When inventory is depleted and reaches a reorder point, new orders to suppliers are generated. When suppliers deliver the orders, the inventory is augmented, and new

orders are stopped until it is depleted again, generating a balancing loop. Delays occur in ordering and in delivery and can generate oscillations in inventory levels.

- The factors influencing the orders to suppliers, but only with links of information, are (1) the reorder point factor, which will be triggered when inventory is at the reorder point level, notifying the company to ask for new orders, and (2) the supplier capacity, which will notify the suppliers of the amount of supplies that can be delivered. Finally, the cash availability factor, determines if the company has enough cash to place an order with the suppliers.
- Production generates finished products, which can be on time or not. Met orders will create a reinforcing loop generating more orders, more production, and more finished products. On the other hand, unmet orders will generate a balancing loop, which will lower the amount of new orders and generate less production, less finished products, and less unmet orders.
- Production is affected by the production capacity factor, which depends on the productivity and the number of workers. These factors are all linked as information and not as a direct tangible flow.

The two diagrams combined represent the company's internal system (*see Figure 8*):

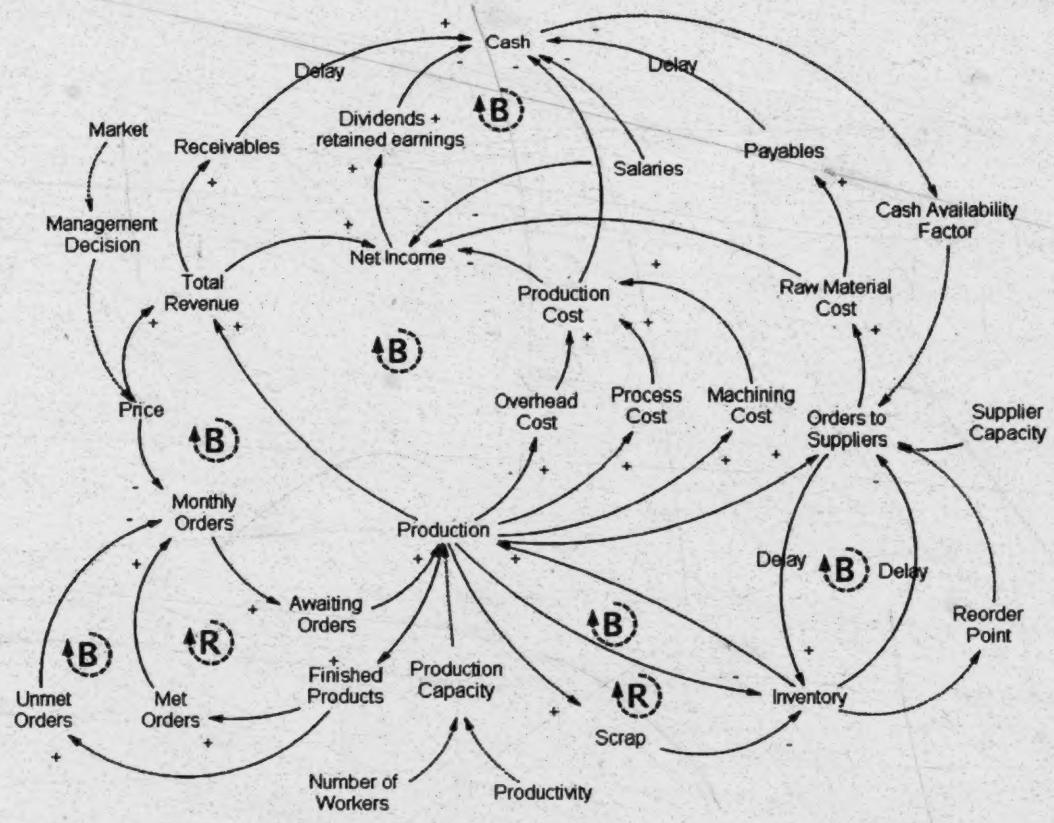

Cash
Delay
Dividends + retained earnings
B
Market
Receivables
Salaries
Payables
Delay
Cash Availability Factor
Management Decision
Net Income
Total Revenue
Production Cost
Raw Material Cost
B
Price
B
Overhead Cost
Process Cost
Machining Cost
Orders to Suppliers
Supplier Capacity
Monthly Orders
Production
Delay
B
Delay
Awaiting Orders
Reorder Point
B
R
Finished Products
Production Capacity
R
Inventory
Unmet Orders
Met Orders
Scrap
Number of Workers
Productivity

Figure 8.- Causal Loop of the Internal System of the Company

Once the internal system was described by using causal loops, the second stage continued. In this step, a second survey was carried out to analyze what external factors influenced the business performance (*see Appendix 2 for second survey*).

Considering that the environment (the external system) interacted with the internal system through the orders, which were directly related with sales, the main factors to be analyzed were those influencing sales.

For a better understanding of the company's environment, an external expert in the industry was also consulted to expand the criteria[4]. After the survey and the expert's interview, it was determined that the different markets served by the company had to be separated in order to identify the influences on each one.

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[4] Interview with Chris Dmytruk, APEGGACouncilor.

For different markets were identified:

1) The Oil Extraction Industry: Oil extracting plant development in northern Alberta.
2) Petrochemical Industry: Maintenance activity in current oil processing plants. This market was considered in this study to be part of the Alberta oil industry.
3) Other National Industries: Canadian markets outside the province of Alberta.
4) International Market: Supply to countries other than Canada, mainly the U.S.

These four categories were created because the company's manger and the expert interviewed considered that each of them behaved distinctively:

- The Oil Extraction Industry depended directly on the plant development in the region. This development was considered to be influenced by the price of oil, only in the long term (15 years or more). The plant construction projects are major investments that require many years for completion, so temporary fluctuations in the oil price do not affect the planned decisions. However, if the oil price is at a constant high level, oil companies have more money and can plan more construction in the long term.
- The Petrochemical Industry depended on the number of plants that were already working and needing maintenance. However, even if this industry has a steady demand, it is influenced in the same way as the oil extraction business, by the entire oil industry's growth trends. Therefore, both industries can be merged into a single industry variable.
- The Other National Industries and the International Sales accounted for mainly standardized products that were considered to be influenced by international competition,

which is influenced mainly by the exchange rate CAD-USD. However, the last two categories were separated since the company's manager had mentioned that International Sales were paid for in USDs, so that the exchange rate with the CAD has the opposite effect. The whole set of external influences can be represented in the causal loop diagram form as follows (*see Figure 9 for external influences causal loop diagram*):

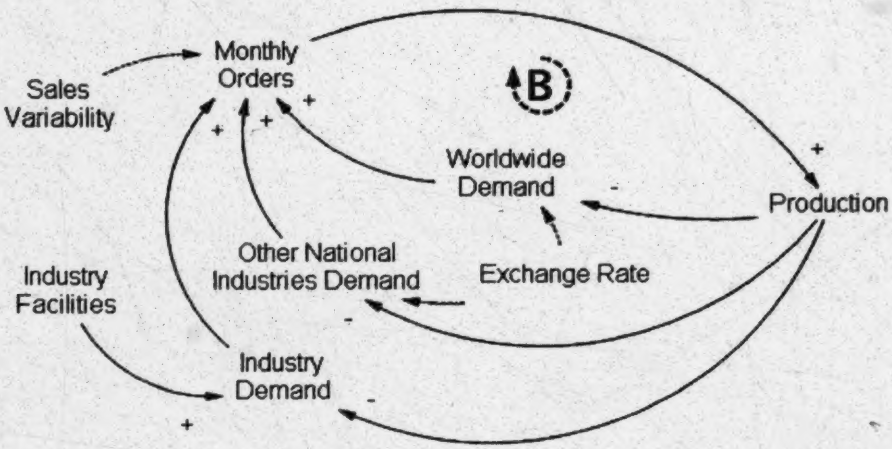
Monthly Orders
Sales Variability
B
+
+
+
+
Worldwide Demand
-
Production
Other National Industries Demand
Exchange Rate
Industry Facilities
-
Industry Demand
-
+

Figure 9.- External Influences causal loop diagram

The diagram represents how the monthly orders come from the Industry demand (the oil industry including the petrochemical market), the "Other National Industries" demand (as defined previously as the analyzed company's national sales excluding those of the oil industry of Alberta) and the worldwide demand (or international sales). As demand increases, the company's monthly orders also increase, but at the same time, as more products are supplied to the market, demand is diminished.

The External Influences diagram also revealed that the number of industry facilities (extraction plants already built) influences the industry demand. Moreover, the exchange rate influences the "Other National Industries" and "International Sales." Furthermore, this diagram also represents the variability of sales due to the normal operations of clients, who require supplies at different periods of time.

Once the external influences model had been designed, it could be integrated with the internal model. The final integrated causal loop diagram is as follows (*see Figure 10 for the final integrated causal loop diagram*):

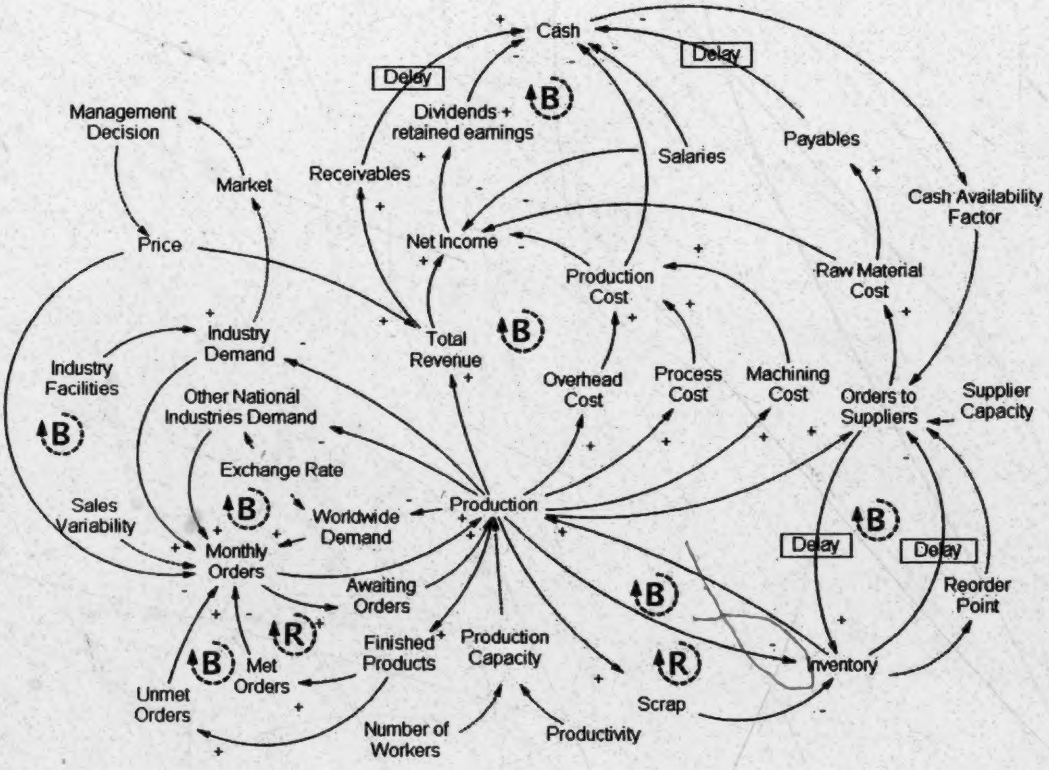
Cash
Delay
Delay
Dividends + retained earnings
B
Management Decision
Market
Receivables
Salaries
Payables
Cash Availability Factor
Price
Net Income
Production Cost
Raw Material Cost
Industry Demand
Total Revenue
B
Industry Facilities
Other National Industries Demand
Overhead Cost
Process Cost
Machining Cost
Orders to Suppliers
Supplier Capacity
B
Exchange Rate
Sales Variability
B
Worldwide Demand
Production
Monthly Orders
B
Delay
Delay
Reorder Point
Awaiting Orders
B
R
Finished Products
Production Capacity
Unmet Orders
B
Met Orders
R
Inventory
Scrap
Number of Workers
Productivity

Figure 10.- Integrated Causal Loop Diagram

This integrated causal loop diagram represents the company's operational structure and the external factors influencing it. However, it does not provide quantitative information or a way of looking at the accumulations and flows of the tangible and intangible factors interacting in the business's normal operations. For this reason, stocks and flows diagrams were chosen in order to complete the intended simulation model. This topic is discussed in the next section. Moreover, other factor could have been considered but were eliminated.

In the internal sector:

- More production variables, such as each worker's productivity and specific processing times, were not considered because no data were available, and also because the main purpose was to describe the company's general behavior and not to describe it in detail.
- Variables on the Balance Sheet, such as debt and assets, were eliminated since the purpose was to simulate the company's entire operations, and not the financial management. Furthermore, since the company is not planning to expand, its control of the assets and debts was not relevant.

In the external sector:

- The oil price was eliminated due to its long-term influence on plant development, and therefore, due to the difficulty of finding a forecast that could be accurate for such a long period of time.
- The company's overseas' competition (mainly Chinese) was eliminated for two reasons: (1) in the oil industry of Alberta requires valves that are non-standardized pieces, and according to the consulted expert, the real threat from overseas

competition is in standardized product, which can be manufactured everywhere else; and (2) for "Other National Industries" and "International Sales," for which the main market is for standardized pieces, the company did not have exact data on where their products go, so they could not be related to the competition since the client were unknown.

- The impact of quality on sales was eliminated because the company does not have a formal quality management system installed, so not enough data are available on how the company rates in terms of quality and on how the customers perceive the quality of the company's products.
- Variables related to the environmental, social responsibility, organizational health and safety, and their management systems were not installed as formal systems in the analyzed company, so no data were available for them.

3.3.3 Development of stocks and flows simulation model

For developing the stocks and flows model, it was decided to use specialized SD software that could also be used to perform the simulation. The SD computer programs available in the market include: PowerSim, DYNAMO, Ithink, Stella, and VenSim (Olson et al., 2005). Stella was chosen for this model because of the researcher's previous experience with this software and its use in the preceding project in the same company. The first step in the development of the stocks and flows diagram was to develop a sectors diagram (*see Figure 11 for the first sectors diagram*).

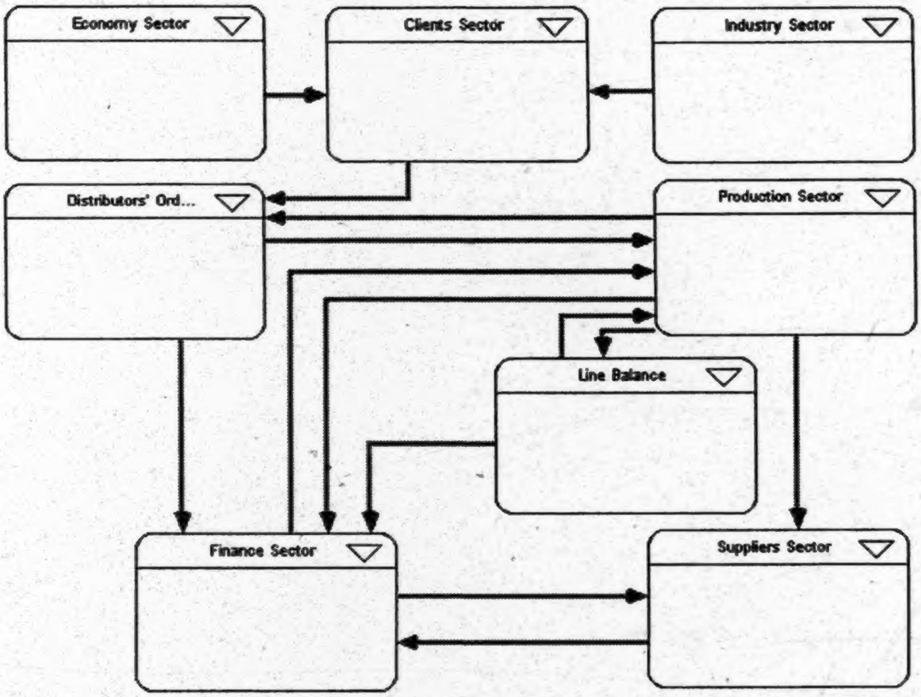
Economy Sector
Clients Sector
Industry Sector
Distributors' Ord...
Production Sector
Line Balance
Finance Sector
Suppliers Sector

Figure 11 .- First sectors diagram of simulation model

This diagram identifies the different sections of the model and is based on the different subsystems identified when developing the causal loop diagrams. This diagram also has the advantage representing the model in a more organized way than the causal loop diagrams allow.

At the diagram's top-left and top-right corners, the external subsystems are identified as the Economy and the Industry sectors. They both have external variables that influence sales, and they were integrated into the Clients sector so that, if necessary, more external factors could be integrated into the model. At the same time, the Clients sector, which represents the influence of external factors on sales, affects the Distributors Orders sector by modifying the number of orders that the company has.

In the diagram's structure, the orders placed by distributors influence the Production sector, since as more orders are received more production is required. Moreover, if more orders are obtained, and more production is started, the production centre influences the Finance sector since more costs are generated. The Finance sector thus contains the records of costs generated by production and handling orders, as well as the revenue obtained from delivered products. Furthermore, this sector is related to the Suppliers sector by providing the cash necessary to place an order for materials.

The Production sector has a relation with the Supplier section because when more production is required, more materials will have to be order from the suppliers. The Production sector is also related to the Line-Balancing sector, in which it is calculated how the work is divided among each of the shop floor workers.

At this point, the first stocks and flows model was developed to represent the company's dynamic behavior because the Stocks and Flows best represent the dynamic of accumulations, inflows and outflows in a system (in this case, the company). Furthermore, since most of the existing SD computer simulation software that uses Stock and Flows diagrams, developing one diagram of this kind in advance is helpful even if no data have yet been obtained (*see Appendix 3 for the first Stocks and Flows model*).

To test the ability of the Stocks and Flows diagram to represent the company's behavior, this diagram needs to be filled with data, simulated by using a software, and then validated against real data. These topics will be discussed in the next sections.

3.3.3.1 Data gathering

In order to carry out the simulation after the first Stock and Flows model had been developed, it had to be filled with data collected from the company and outside sources. The initial internal information was obtained from an interview with the company's management, at which a table was filled out (*see Appendix 4 for table of data*). More information was obtained after a revision of two years of financial statements.

External information was obtained depending on the market. Each of the company's three main markets -- the oil industry of Alberta (including the petrochemical industry), the Other National Industries market, and the International market – each has its own behavior and drivers.

For the analysis of the oil industry, the investments in new plant development were researched in electronic sources (TD Canada Trust, 2005), in accordance with what the consulted experts considered to be the main factor in the industry's growth. Based on this data, the industry growth factor was calculated. See *Table 2 for calculations*.

In Table 2, the top row presents the capacities, in tons of bitumen, of the extractions plants planned to start operations in each of the years from 2005-2016. The second row presents the total expansion, or the sum of all the new plants' capacities. The third row presents the total production of bitumen so that the new extraction plant construction could be added to obtain each year's total estimated production capacity. The fourth row presents the growth as a percentage of each year's predecessor (the year's capacity minus the last year's capacity over the last year's capacity).

Year	2005	2006	2007	2008	2009	2010
Extraction Plants Construction Estimated Capacities (In tons of bitumen)	110000 70000 10000 40000 15000	30000 40000 10000 27000 30000 25000 25000	60000 35000 47500 30000 70000 25000 80000	70000 105000 133000 25000 12500	30000 12500	135000 49000 25000 60000 300000 200000 23750 25000
Total Expansion	245,000	187,000	347,500	345,500	42,500	817,750
Total extracted bitumen	1,366,000	1,510,000	1,858,000	2,309,000	2,502,000	2,847,000
Growth Percentage	*30%*	11%	23%	24%	8%	14%
Monthly Growth Factor	1.022	1.009	1.017	1.02	1.006	1.011
Simulation Months	Jul - Dec 1to6	Jan-Dec 7to18	Jan-Dec 19to30	Jan-Dec 31to42	Jan-Dec 43-54	Jan-Dec 55to66

Year	2011	2012	2013	2014	2015	2016
Extraction Plants Construction Estimated Capacities (In tons of bitumen)	70000 30000 23750	91000	110000 100000	0	0	N/A
Total Expansion	123,750	91,000	210,000	0	0	N/A
Total extracted bitumen	3,191,000	3,381,000	3,641,000	3,727,000	3,597,000	N/A
Percentage of growth	12%	6%	8%	2%	-3%	N/A
Monthly Growth Factor	1.009	1.005	1.006	1.002	0.998	N/A
Simulation Months	Jan-Dec 67to78	Jan-Dec 79to90	Jan-Dec 91to102	Jan-Dec 103to114	Jan-Dec 115to126	N/A N/A

Table 2. – Calculations of Industry Factor Growth (N/A = Not available)

In the case of the first year, the company's growth trend for the first 6 months of 2005, compared to the first 6 months of 2004, was used, to obtain 30%. After calculating the industry's yearly growth, the monthly growth factor was also calculated. In this case, the variable was represented as a factor of the previous month's capacity, so that when it was multiplied over the 12 months, the year's growth was obtained. For example, if we multiply 1.0221 by itself 12 times, we will obtain 1.30 or 30% growth, which corresponds to the growth in the year 2005.

Other factors such as technology changes can influence the need for valves for the industry. The company can overcome such factors by product design changes as well as new materials utilization. However, due to the inconsistency of these changes, and since the company is aware of this problem and continually renews designs and materials when customers require renewal; it was decided to eliminate this effect from the simulation model. The analysis of the oil industry market's behavior on technology changes is a topic of research that is outside the scope of this research but could be included to possibly improve the model.

Other National Industries and International sales were correlated with the exchange rates of the US Dollar (USD) and the Canadian Dollar (CAD). Thus, information was gathered about the monthly average exchange rate between the CAD and the USD during the same two years for which the financial information had been obtained. *See Table 3 for the two years of exchange rates CAD per USD.*

Month	EXRate US/CAD	Month	EXRate US/CAD
May-03	1.3833	**May-04**	1.3778
Jun-03	1.3517	**Jun-04**	1.358
Jul-03	1.3811	**Jul-04**	1.3219
Aug-03	1.3946	**Aug-04**	1.3119
Sep-03	1.363	**Sep-04**	1.2875
Oct-03	1.3228	**Oct-04**	1.2472
Nov-03	1.3124	**Nov-04**	1.1957
Dec-03	1.3124	**Dec-04**	1.2176
Jan-04	1.2967	**Jan-05**	1.2256
Feb-04	1.3289	**Feb-05**	1.2383
Mar-04	1.3281	**Mar-05**	1.2157
Apr-04	1.3418	**Apr-05**	1.2365

Table 3: Monthly Average Exchange Rates CAD per USD (Bank of Canada, 2006).

After analyzing the sales data of the Other National Industries and the International markets, it was determined that

1) International demand, which is mainly in the US, was not influenced by the exchange rate USD-CAD because the company made sales in US dollars, and therefore, no price variation occurred due to an exchange rate with the CAD that could affect the customer's buying decision. The influence of the exchange rate CAD vs. the Euro was evaluated, but this rate showed no correlation. Other currencies were not contemplated because sales to countries other than the US and the European countries just represented less than 1% of the total sales.
2) The Other National Industries demand has a correlation with the CAD-USD exchange rate by a factor of 0.56 (over 1). For this calculation, the sales in the Other National Industries market were separated from the 2 years of historical overall sales. Later, this historical demand was correlated with the previously introduced exchange rate CAD per USD data, by using Microsoft Excel (*see Table 4 for the array of data*). The formula used by the software is the following:

$$\rho_{x,y} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \mu_x)(y_i - \mu_y)}{\sigma_x \cdot \sigma_y} \qquad -1 \le \rho_{xy} \le 1$$, (Microsoft, 2002)

where

$\rho_{x,y}$ = Correlation coefficient between an array of data x and an array of data y.

μ_x = Mean of the array of data x

μ_y = Mean of the array of data y

x_i = each element on the array of data x

y_i = each element on the array of data y

n = number of pairs of data.

Month	National Sales	EXRate US/CAD
May-03	$ 119,532.92	1.3833
Jun-03	$ 104,489.72	1.3517
Jul-03	$ 149,946.00	1.3811
Aug-03	$ 198,570.57	1.3946
Sep-03	$ 210,813.21	1.363
Oct-03	$ 50,349.92	1.3228
Nov-03	$ 40,864.22	1.3124
Dec-03	$ 97,025.73	1.3124
Jan-04	$ 17,194.80	1.2967
Feb-04	$ 9,718.77	1.3289
Mar-04	$ 6,793.15	1.3281
Apr-04	$ 18,132.22	1.3418
May-04	$ 58,295.82	1.3778
Jun-04	$ 58,591.97	1.358
Jul-04	$ 29,253.53	1.3219
Aug-04	$ 12,947.97	1.3119
Sep-04	$ 43,743.97	1.2875
Oct-04	$ 50,873.51	1.2472
Nov-04	$ 22,947.40	1.1957
Dec-04	$ 31,134.11	1.2176
Jan-05	$ 20,269.81	1.2256
Feb-05	$ 35,629.15	1.2383
Mar-05	$ 70,462.75	1.2157
Apr-05	$ 11,199.88	1.2365
Correlation	0.56	

Table 4 – Correlated data.

For the correlation coefficient to be meaningful, it has to be squared, to obtain a "squared correlation" of 0.32 (0.56 times 0.56). According to Rummel (1976), this result means that the first set of data (for the exchange rate) had an influence in 32 % of the situations in the other set of data (in this case, for the buying decision's involving orders). Therefore, 32% of the sales volume followed the same distribution as the exchange rate.

Using the exchange rate was useful to simulate the external influence of the Other National Industries demand, but not for the International demand. Therefore, it was decided to use the exchange rate for Other National Industries, and not to use it for the International demand. Other factors such as overseas competition may impact sales in each of the markets. However, the company supplies such a great variety of industries, that another meaningful factor cannot be included in the simulation. Moreover, any other factor that might exist would be included in a general sales variable based on the historical data.

By using all the generated data from the correlations, the model was filled out. The first formulas were developed, but they were not finished until the final model was developed, so they will be explained in Chapter 4. (*See Appendix 5 for the second model obtained after filling it with data*). At this point, the model needed to be "debugged" for it to be operational and helpful for performing a sensitivity analysis.

3.3.3.2 Debugging Process

The process of debugging consists of finding errors in the simulation model as well as inconsistencies causing unexpected behaviors. According to Richmond et al. (2000), the debugging process can be done in many ways, including

1) Substitution of different values: by this method, numbers can be enlarged or minimized dramatically in order to identify the model results' tendency. If the results do not show the tendency expected or do not show any change at all, the model must be verified. A useful practice is to substitute with zero.
2) Changing the time frame: by expanding or even shrinking the time frame, tendencies and abrupt changes can be identified in the behavior of the simulation, so that errors can be found.
3) Comparing results with real data: this process involves finding the gaps between the model's data and the real data. This process can also validate the model and can be done several times until errors in the model are corrected.

The first two debugging techniques were applied in the model, and many changes were performed to the model and the input data so that errors and inconsistencies were eliminated. The main changes can be summarized as follows:

1) Formulas were modified to include a condition for zero or absent values. For example, what would happen if the company stopped operations and its revenue were zero? In such a case, a point must be reached at which orders to suppliers as well as the whole financial process stop.
2) Inclusion of a time identifier so that projections can be related to it. For example, if the model is to start simulating on January of next year (2007), the model can be fixed to use industry and economy trends starting on the specified date and not from the initial data, which correspond to June, 2005.
3) Correction of factors that did not present the expected behavior. For example, production does not depend on workers' productivity, but is totally the opposite.

Productivity, as it is measured in the company, is the units produced divided by the number of workers. However, productivity does have a limit capacity, which is exactly what was important to represent. This behavior is included in the final model.

4) Integration of exceptions. For example, negative numbers cannot be present in certain variables such as revenue (losses are reflected in the income variable), inventory and number of workers.
5) Assignation of initial values. Since the simulation starts at a given point in time, and not from the start-up of the company, many variables must have accumulated amounts. For example, a certain level of payables and receivables must have accumulated.
6) Elimination of the Line Balance Sector, which showed a delay with respect to the rest of the simulation. The "Line Balance Sector" is the sector in which how the work is distributed among the different workers is calculated. Instead of including the whole Line Balance Sector, it was replaced by the direct relation between the total working load and the different production sub-sectors.

After these modifications were made, the process of validation started when the third debugging technique was applied. This process is explained in the next section.

3.3.3.3 Validation Process

The first process of validation was to compare simulated data against past data, which had to show the increase estimated by the manager of the company. After the first simulation a much higher difference was found, so the model needed to be revised. For the revision process, the company's manager was contacted in order to verify the information on company trends simulated. He believed the values were too high, so the model needed to be fixed. The manager expected a maximum increase in sales of 20% for the simulated year compared to the previous year. With this figure in mind, the different factors were verified to find the problem.

It was discovered that the model had not considered the variation due to other external factors outside the model's scope. For example, sales were not constant every month due to different clients' needs and seasonal behaviors. Thus, it was decided to include a "Sales Factor" based on the variation of the historical data. This factor affected only the portion of data outside the influences of the factors already included. It was calculated by obtaining the historical data's mean and standard deviation and dividing them by the mean itself so that a factor of normal distribution with mean 1 and its corresponding standard deviation could be obtained.

After adjusting the model to include the new factor, some other iterations of data comparison were made to refine the model. Other minor changes were made such as fixing the value of the normal distribution to always represent the same random numbers (a "seed" was used; each seed produced a different set of random numbers). At the end of the process, the model's results were presented again to the manager of the company until he finally accepted them[5]. This version of the model showed an accumulated difference of 17%. *See Table 5 for comparison past vs. simulated trends.*

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[5] The company's manager accepted the model for the purpose that it was made for, and suggested a new study on technology changes in the oil industry, since such a study could be useful for planning.

Month	Past Data	Simulation
May	361,250	1,100,000.00
June	920,333	744,105.19
July	400,837	858,558.64
August	229,161	903,975.73
September	781,483	935,099.91
October	612,841	906,981.66
November	444,210	758,049.58
December	690,018	714,546.87
January	733,257	717,091.50
February	1,557,198	868,615.57
March	885,337	925,859.63
April	1,195,244	945,645.66
Total	$ 8,811,168.68	$10,378,529.94
	Accumulated difference: 17%	

Table 5 .- Comparison of past data vs. simulation trends

The second validation process was to compare the simulation data against the real data. Since the data available were historical, the model was used to simulate the same time period, and these data were compared with the original ones. *The validation data are presented in Table 5 and figure 12.*

Table 5 reveals that the total difference between the actual data and the simulated data is -6%. As well, this table shows that the total absolute deviation of the monthly data is an aggregated 28%. Moreover, the standard deviations, which must be similar, have close values (294,043 and 187,271 respectively).

Figure 12 shows how the actual and simulated data show the same pattern, and the main difference is only sales jumps due to unexpected orders. All these comparisons show that the simulation does represent the behavior of the business. The entire simulation model will be explained in the next chapter.

Month	Actual	Simulation	Diffrence	Absolute Value
June	589,917	654,821.58	64,905	64,905
July	610,724	726,748.58	116,025	116,025
August	879,146	713,318.51	(165,828)	165,828
September	517,879	738,456.37	220,577	220,577
October	541,381	628,427.58	87,047	87,047
November	498,527	470,904.38	(27,623)	27,623
December	361,897	435,627.82	73,731	73,731
January	556,782	444,230.76	(112,551)	112,551
February	810,596	607,751.46	(202,845)	202,845
March	720,834	745,593.74	24,759	24,759
April	894,633	641,039.14	(253,594)	253,594
May	361,250	456,588.25	95,338	95,338
June	920,333	304,984.98	(615,348)	615,348
July	400,837	261,847.61	(138,989)	138,989
August	229,161	431,964.36	202,803	202,803
September	781,483	645,191.06	(136,292)	136,292
October	612,841	793,888.90	181,048	181,048
November	444,210	840,787.78	396,578	396,578
December	690,018	855,602.62	165,584	165,584
January	733,257	860,966.22	127,709	127,709
February	1,557,198	864,255.27	(692,943)	692,943
March	885,337	867,684.58	(17,652)	17,652
April	1,195,244	825,782.47	(369,461)	369,461
Total	$ 15,793,485.63	$14,816,464.02		4,489,228.05
	Accumulated difference: -6%		Total Deviation	28%
Average	686,673.29	644,194.09		
Standard Deviation	294,043.08	187,271.73		

Table 6.- Validation table.

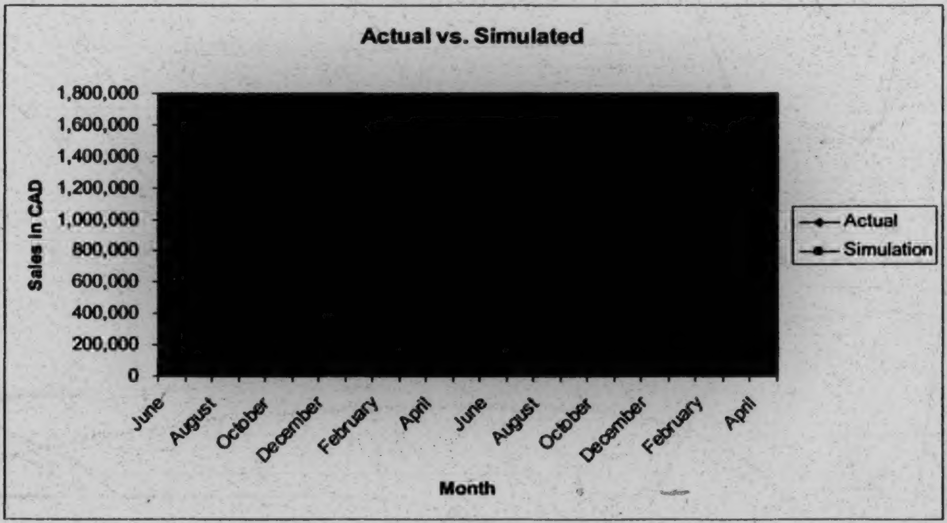

Figure 12 .- Actual vs. Simulated Graph

Chapter 4 – Results Of The Study

4.1 Introduction

After the simulation model was created, a final simulation model was obtained to be the basis of this study. In this chapter, the results of this simulation model will be presented, including (1) The simulation model flows diagram explanation; (2) the internal data including formulas, tables of data, and factors; and (3) the tables and graphs of results. This step is the last one prior to presenting the analysis of the results and their application (the topic of Chapter 5).

4.2 General Description of the Model

The model as a whole is the integration of 3 internal sectors with 5 sub-sectors, and 1 external sector with 2 sub-sectors (*see Figure 13 for the sectors diagram of the final model*). The 3 internal sectors are

1) The Financial Sector, which contains all the information related to financial measures;
2) The Production Sector, which contains all the non-financial variables related to the manufacturing of products. This sector include 4 sub-sectors, 3 to represent the products ANSI 150, ANSI 300 and ANSI 600, and 1 to represent the remaining type of products, which are called in this study "Special Orders."

3) The Orders Sector, which represents all the issues related to the sales system. This sector includes the orders waiting in the system as well as the new orders for every type of product in the company.

On the other hand, the "external sector" includes the factors influencing future sales. This sector includes 2 sub-sectors:

1) The Industry Sector, which is the representation of the industry development's influence on the company's future sales.
2) The Economy Sector, which represents the economic factor's influence on future sales.

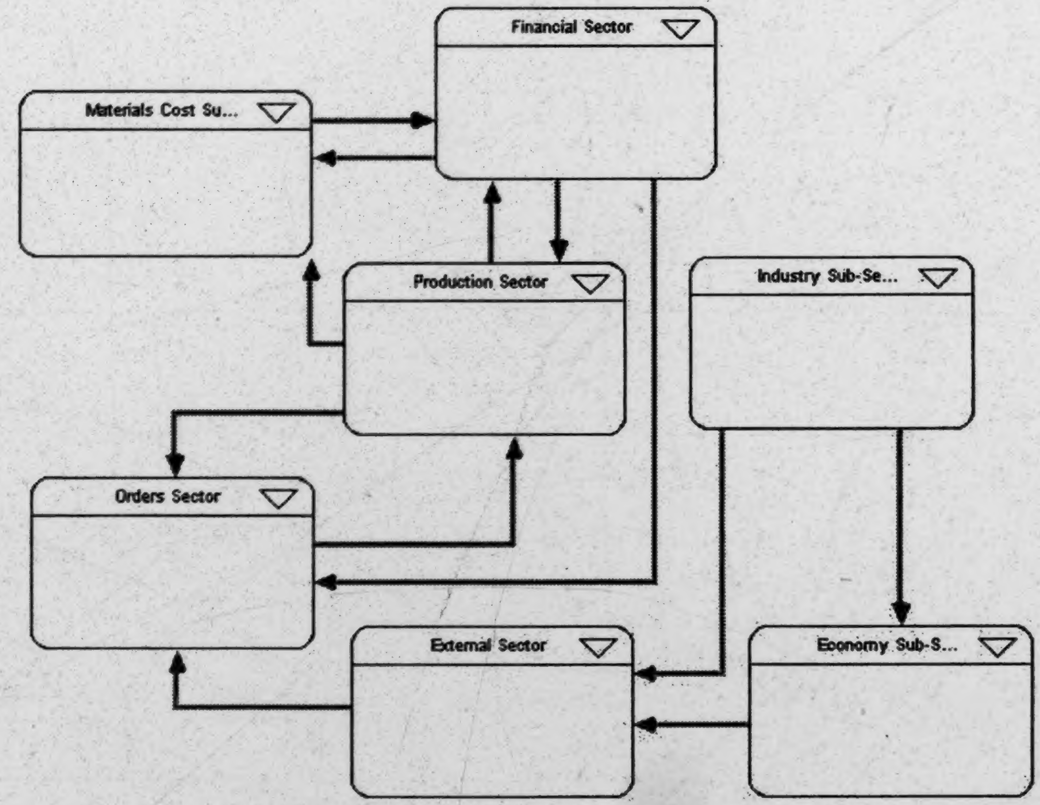
Financial Sector
Materials Cost Su...
Production Sector
Industry Sub-Se...
Orders Sector
External Sector
Economy Sub-S...

Figure 13.- Sectors Diagram of Final Model

All sectors and sub-sectors have a total of 126 variables, 25 stocks, and 50 flows, which are inter-related by links and formulas (*See Appendix 6 for the formulas*). The simulation results are presented in 4 different tables and 8 graphs. Their contents are explained in the next three sections.

4.3 Description Of Internal Sectors and Sub-sectors

4.3.1 Financial Sector

This sector defines the company's cash situation (*See Figure 14 for the financial sector diagram*). The stock (container) "Cash", which contains the available cash at a given moment in time, is increased by the "Cash In" flow and depleted by the "Cash Out" flow. The first flow represents the cash obtained when Receivables are paid by the clients. The second flow represents the cash that goes out when paying costs, and when income is paid as dividends or retained earnings. Another variable, the "Cash for Inventory," reflects the ongoing cash for buying inventory.

In the Financial Sector, Receivables and Payables are represented as follows:

1) "Receivables" is a stock in the form of a conveyor, which is represented in the software as a time delay. This stock is depleted by the "Paid Receivables" flow, which is controlled by the maximum and minimum times in which the company pays receivables. "Receivables" Stock is increased by the "Revenue" flow, which represents the money gained from "Total Sales."

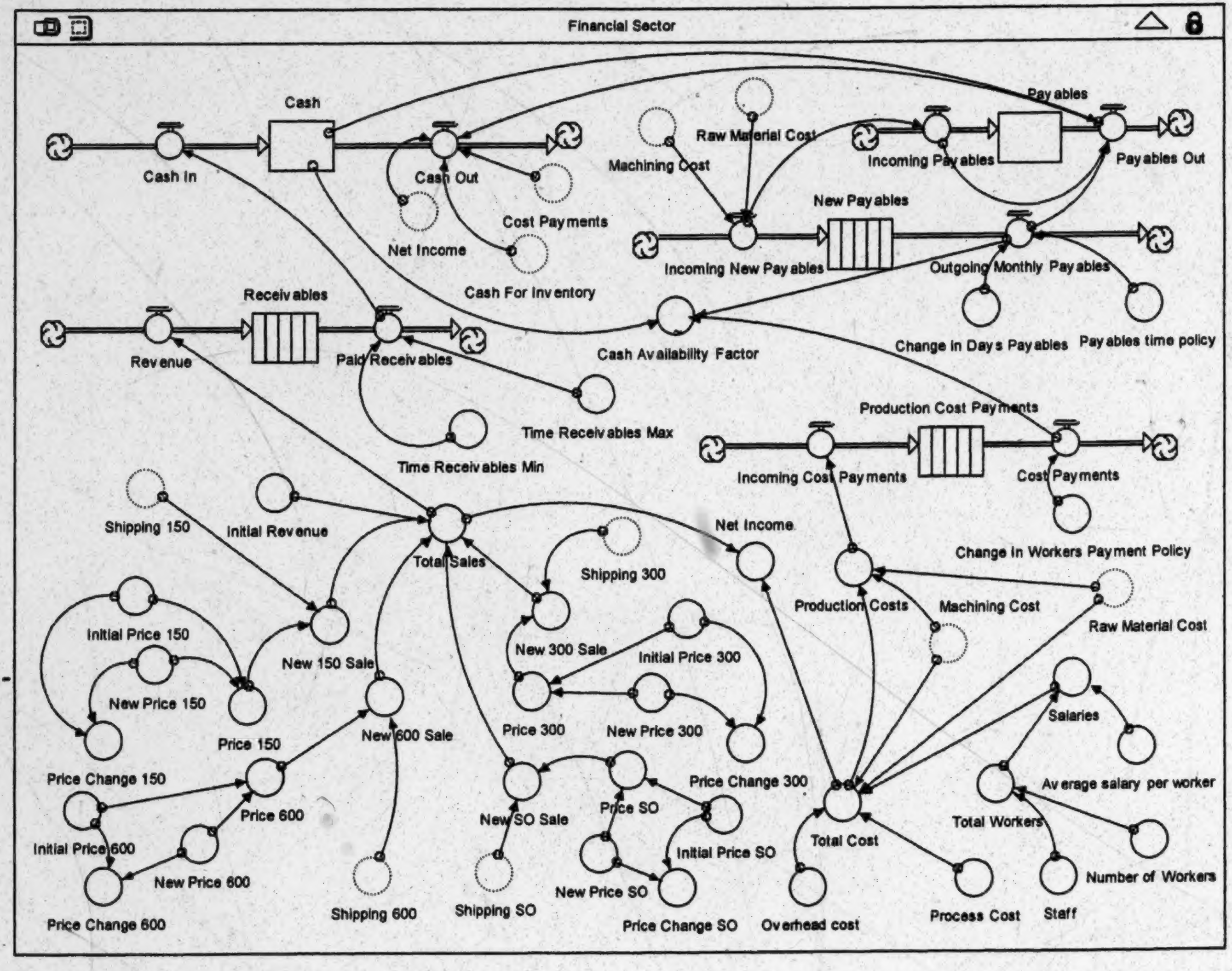
Financial Sector
Cash
Cash In
Cash Out
Net Income
Cost Payments
Cash For Inventory
Receivables
Revenue
Paid Receivables
Time Receivables Max
Time Receivables Min
Machining Cost
Raw Material Cost
Payables
Incoming Payables
Payables Out
New Payables
Incoming New Payables
Outgoing Monthly Payables
Change in Days Payables
Payables time policy
Cash Availability Factor
Production Cost Payments
Incoming Cost Payments
Cost Payments
Change in Workers Payment Policy
Shipping 150
Initial Revenue
Total Sales
Net Income
Shipping 300
Production Costs
Machining Cost
Raw Material Cost
Initial Price 150
New Price 150
New 150 Sale
Price 150
New 300 Sale
Initial Price 300
Price 300
New Price 300
Salaries
Average salary per worker
Price Change 150
New 600 Sale
Price Change 300
Total Workers
Price 600
New SO Sale
Price SO
Initial Price 600
Initial Price SO
Total Cost
New Price 600
New Price SO
Number of Workers
Price Change 600
Shipping 600
Shipping SO
Price Change SO
Overhead cost
Process Cost
Staff

Figure 14 .- Financial Sector Diagram

The last variable is the sum of the revenue from the sales of all products, which in the model is calculated by multiplying the price of each product times the completed pieces being shipped (for example, "Price 150" times "Shipping 150"). Revenue and variables such as "Price Change", "Initial Price" and "New Price," which were introduced for simulation purposes only, have an initial value.

2) Payables are represented in a more complex way than receivables since the former depend on the company's cash availability. Therefore, a stock called "Payables" is depleted by the flow "Payables Out" and increased by the flow "Incoming Payables." This Stock and Flows structure is driven by another one which includes the conveyor-type stock "New Payables." The last stock is fed by the "Incoming New Payables" flow, which is the sum of the suppliers' costs ("Raw Material Cost" and "Machining Cost"). It is also depleted by the "Outgoing Monthly Payables" and controlled by the "Payables time policy."

Two other variables are calculated in the Financial Sector:

1) The "Cash Availability Factor" is the result from the cash available minus the payables and other costs payments. These other costs are driven by another structure in which the conveyor-type stock "Production Cost Payments" is fed by "Incoming Cost Payments" and depleted by "Cost Payments", which can be changed by the workers' payment policy. At the same time, "Incoming Cost Payments" includes the "Production Costs", which is the "Total Cost" minus the "Raw Material Cost" and "Machining Cost."

2) The "Net Income" is the rest of "Total Sales" minus "Total Cost," which is the sum of the "Overhead Cost," "Process Cost," "Salaries," "Machining Cost," and "Raw

Material Cost." "Salaries" is defined by the multiplication of "Total Workers" times "Average Salary per Worker." Furthermore, "Total Workers" is the sum of "Staff" (administrative workers) plus "Number of Workers" (production workers).

This simulation model did not include the impact of the cost on the pricing decision. The price of products in this company is the result of a negotiation with mainly the distributors, and no data are available on how the costs are related with the price during the negotiation. However, in the simulation, the analysis of the price shows that it should be kept without increases, at least in the short term (2 years or less).

4.3.2 Materials Cost Sub-Sector

This sub-sector defines only the variables "Raw Material Cost" and "Machining Cost" (*see Figure 15 for Material Costs Sector diagram*). Both are defined by the multiplication of their percentage over sales ("Raw Material Percentage" and "Machining Percentage"), times the total sales of each product. These total sales are defined by the multiplication of the parts shipped and their price, for example, "Shipping 150" times "Price 150." This sector also includes the variables' initial values so that the simulation can start properly and the impact on the cost of scrap (by multiplying the scrap rate times the Raw Material Cost and Machining Cost and adding it to the overall cost).

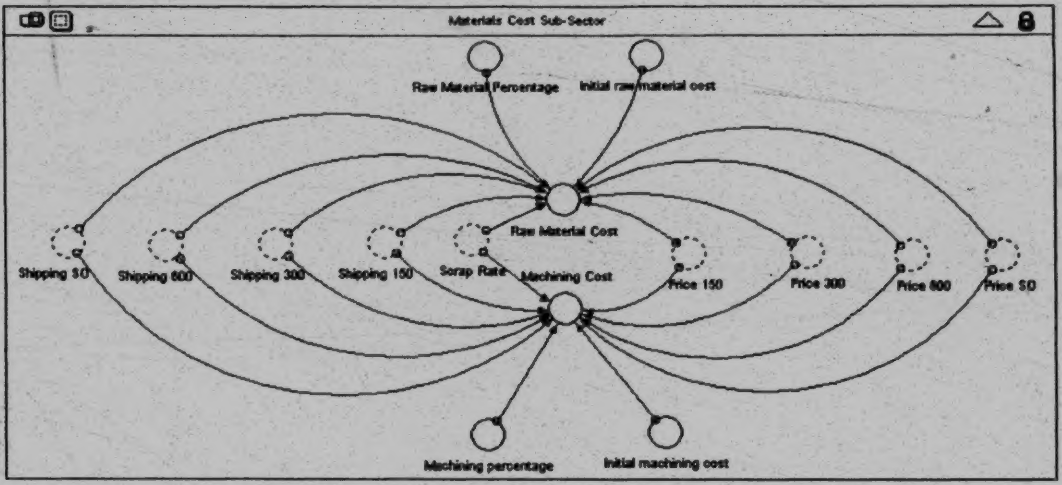
Materials Cost Sub-Sector
Raw Material Percentage
Initial raw material cost
Raw Material Cost
Shipping SO
Shipping 600
Shipping 300
Shipping 150
Scrap Rate
Machining Cost
Price 150
Price 300
Price 600
Price SO
Machining percentage
Initial machining cost

Figure 15 .- Material Costs Sector diagram

4.3.3 Orders Sector

This sector involves the orders (an "order" understood as the order of one single piece of product) for each product that the company is projected to sell, according to the different factors involved. The sector includes four different structures, one for each product analyzed, and one for "Special Orders." Only one structure (the one for the product ANSI 150) will be explained since it represents the other three (*See Figure 16 for Orders Sector diagram*).

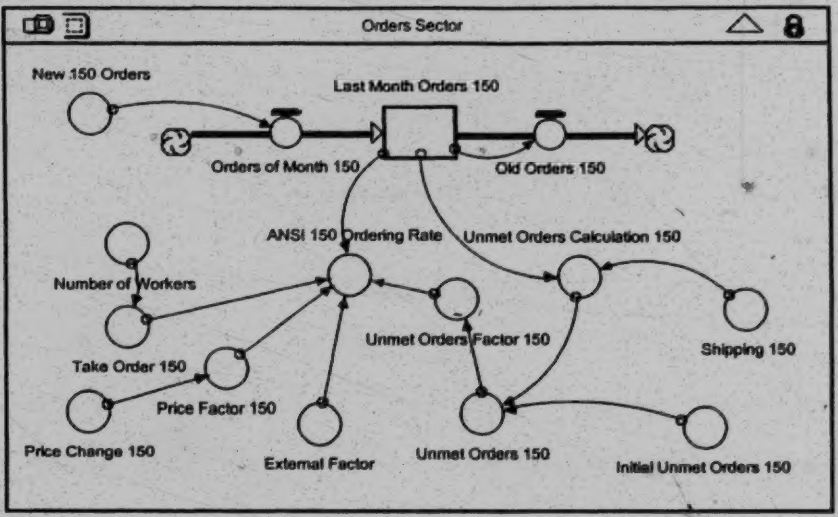
Orders Sector
New 150 Orders
Last Month Orders 150
Orders of Month 150
Old Orders 150
ANSI 150 Ordering Rate
Unmet Orders Calculation 150
Number of Workers
Take Order 150
Unmet Orders Factor 150
Shipping 150
Price Factor 150
Price Change 150
External Factor
Unmet Orders 150
Initial Unmet Orders 150

Figure 16 .- Orders Sector Diagram

The main factor considered in this sector to be the basis for calculation, is the orders that the company had the previous month. The stock "Last Month Orders 150" is fed by the inflow "Orders of Month 150," which depends at the same time on the variable "New 150 Orders." The stock "Last Month Orders 150" represents only the new orders generated in the previous month and does not accumulate them. If the orders are not met, the accumulated orders are not shown in this variable; they are otherwise represented in the stock "Awaiting Orders" in the production sub-sectors. For this reason, the variable "Old Orders 150" was created generated for simulation purposes to deplete the stock each month so that only new orders were represented.

Once defined, the variable of "Last Month Orders 150" was used to calculate the next month orders, called in this model the "ANSI 150 Ordering Rate." This rate is influenced by

1) The "Take Order 150" variable, which determines the decision to take an order if enough workers are available to complete it.
2) The "Price Factor 150," which is the impact on sales of the variation of the product's price ("Price Change 150").
3) The "Unmet Orders Factor 150," which represents the impact on sales of having unmet orders ("Unmet Orders 150"). The last factors are calculated by using the rest: "Last Month Orders 150" minus "Shipping 150" (pieces of 150 product completed and shipped to the client). An initial value is also used to properly start the simulation.
4) The External Factor, which includes all the external influences on sales and will be explained in section 4.4.

4.3.4 Production Sector

This sector includes a small integration diagram and four sub-sectors. The integration diagram presents the calculation of "Cash For Inventory" from its four different sources, and the calculation of the variable "Productivity" (*See Figure 17 for Production Sector Integration Diagram*). This variable is obtained by taking the integrated value of "Awaiting Orders" and comparing it with the production workers available ("Number of Workers"). On the other hand, the sub-sectors are used in the simulation of the production system for each of the three products and the special orders. These sub-sectors are described in the next section.

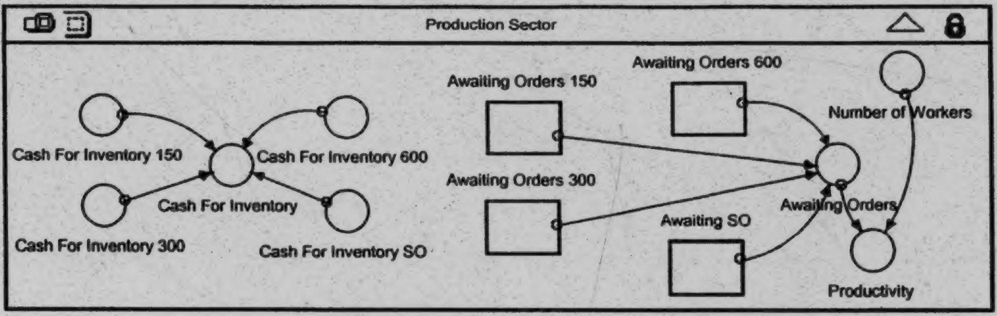
Production Sector
Awaiting Orders 600
Awaiting Orders 150
Number of Workers
Cash For Inventory 150
Cash For Inventory 600
Awaiting Orders 300
Cash For Inventory
Awaiting Orders
Awaiting SO
Cash For Inventory 300
Cash For Inventory SO
Productivity

Figure 17 .- Production Sector Integration Diagram

4.3.5 Production Sub-Sectors

Since every production sub-sector has the same structure, only the production sub-sector for the product ANSI 150 will be described. The behavior of the Production Sub-Sector is driven by two different flows: the awaiting orders flow and the materials flow, both representing a "pull system" based on the clients' orders (*See Figure 18 for the production sub-sector representation*). The awaiting orders are represented by the stock "Awaiting Orders 150." This stock is increased by the flow "New 150 Orders," which has as a source, the "ANSI 150 Ordering Rate," defined in the Orders Sector. The "Awaiting Orders 150" stock is at the same time depleted by the flow "Completed 150 Orders," which depends on the shipping of parts at the end of the materials flow ("Shipping 150").

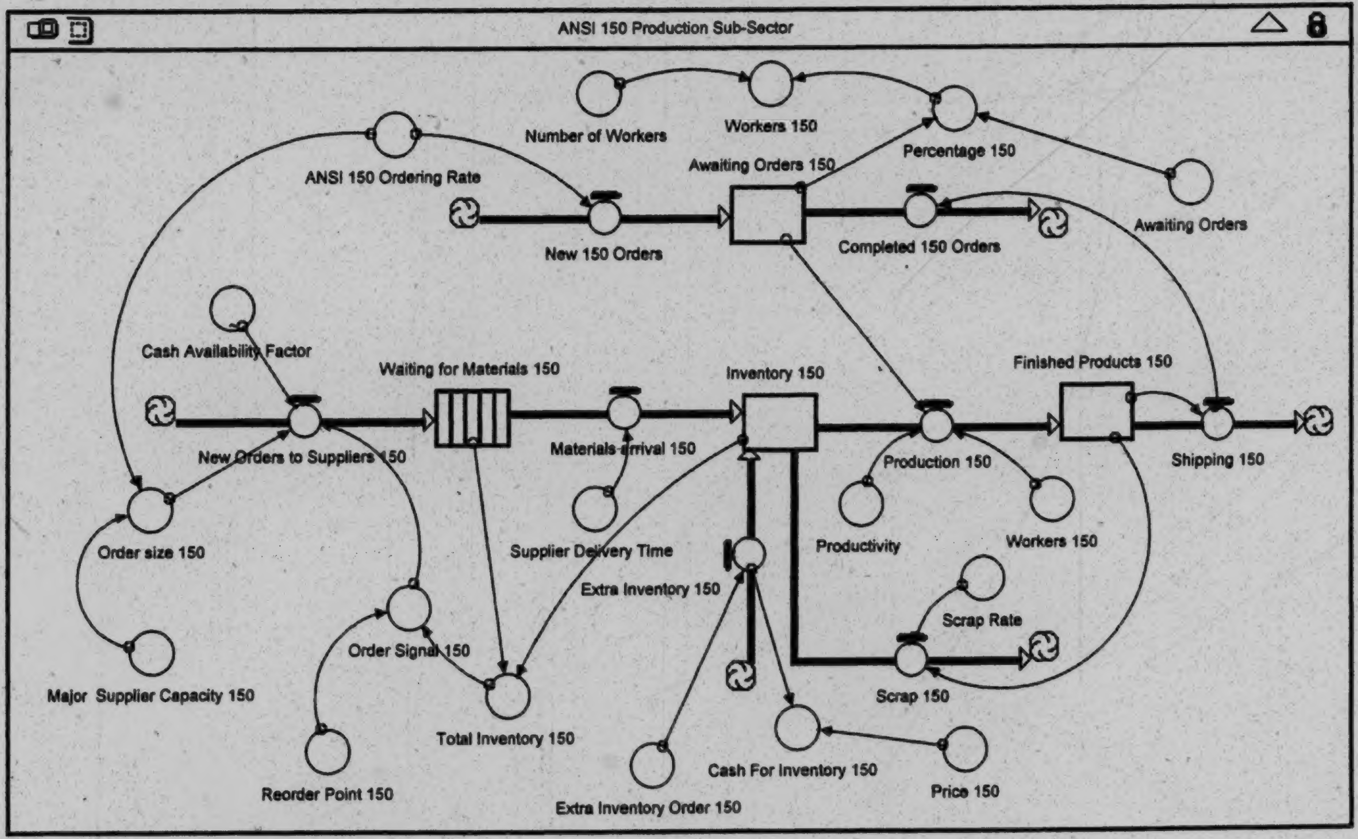
ANSI 150 Production Sub-Sector
Number of Workers
Workers 150
Percentage 150
Awaiting Orders 150
ANSI 150 Ordering Rate
New 150 Orders
Completed 150 Orders
Awaiting Orders
Cash Availability Factor
Waiting for Materials 150
Inventory 150
Finished Products 150
New Orders to Suppliers 150
Materials arrival 150
Production 150
Shipping 150
Order size 150
Supplier Delivery Time
Productivity
Workers 150
Extra Inventory 150
Scrap Rate
Order Signal 150
Major Supplier Capacity 150
Scrap 150
Total Inventory 150
Cash For Inventory 150
Reorder Point 150
Extra Inventory Order 150
Price 150

Figure 18 .- Production Sub-Sector, represented by the ANSI 150 diagram

"Awaiting Orders 150" also influences the "Productivity," which was calculated in the Production Sector's integration diagram. This connection is by the variables "Percentage 150" and "Workers 150," which at the same time are related to "Number of Workers" and "Awaiting Orders" from the Production Sector. This structure calculates the number of workers required to produce the ANSI 150 orders based on the Awaiting Orders 150 and the percentage that it represents from the total, for assigning a certain number of workers ("Workers 150") from the total (*See Appendix 6 as a reference for this calculation*).

The other flow considered in the Production Sub-Sector is the Materials flow. It starts by the incoming flow of "New Orders to Suppliers 150," which feeds the conveyor type "Waiting for Materials 150," which at the same time is depleted by the "Materials Arrival 150" flow, which is controlled by the "Supplier Delivery Time." The flow is started with "Order Signal 150," which occurs when the "Total Inventory 150" reaches the "Reorder Point 150" level. Other factors influencing the "New Orders to Suppliers 150" flow are

1) The "Cash Availability Factor", which determines if enough money is available to place an order.
2) The "Order Size 150," which is the amount of material asked for in each order and based on the "ANSI 150 Ordering Rate" compared with the "Major Supplier Capacity 150."

The flow continues in the stock "Inventory 150," which is fed by the "Materials Arrival 150" and is also fed by the "Extra Inventory 150" when it applies. The "Extra Inventory 150" depends on the variable "Extra Inventory Order 150" and affects, at the same time as "Price 150" the variable "Cash For Inventory 150." Therefore, "Cash" will be depleted by the multiplication of extra inventory orders times the price of them.

On the other hand, "Inventory 150" is depleted by the "Scrap 150" flow and the "Production 150" flow. As a result, the action of production will diminish the inventory, and at the same time, some scrapped pieces will also deplete the inventory as a factor ("Scrap Rate") of the finished products. At the same time, "Production 150" will be the "Productivity" times the number of workers ("Workers 150") and will depend on the current "Awaiting Orders 150".

Finally, the materials flow is completed when the container "Finished Products 150" (which was fed by the flow "Production 150") is depleted by the "Shipping 150" flow. This flow at the same time feeds the "Completed 150 Orders" flow, which diminishes the number of "Awaiting Orders 150."

4.4 Description Of External Sector and Sub-sectors

4.4.1 External Sector

The External Sector contains all the external factors that influence the company's sales (*see Figure 19 for External Sector diagram*). The factor that is directly related in the model with the ordering sector, and that integrates the other ones for simplicity, is the "External Factor." This variable was created so that the model could be easily expanded to include new external factors, if doing so were considered necessary.

Another factor included is the "Sales Factor," which represents the variability of sales due to normal cycles of clients' orders. The other two factors included in the External Sector, the "Industry Factor" and the "Economy Factor," are defined in two different Sub-Sectors, which are explained next.

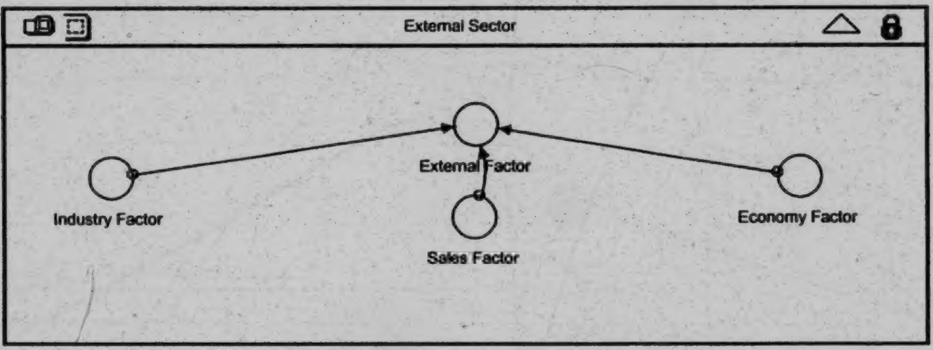

Figure 19 .- External Sector Diagram

4.4.2 Industry Sub-Sector

This Sub-Sector calculates the "Industry Factor" (*See Figure 20 for Industry Sector diagram*), by relating it to the Alberta oil industry trend (the main market of the company analyzed), which has an "Initial Time" value for simulation purposes. This sub-sector takes into account that 34% of the company's sales are in the oil sands industry of Alberta ("Oil Sands Percentage") and that 22% of them are in the petrochemical industry of the same province ("Petrochemical Percentage"). Thus, both markets can be related to the entire oil industry's growth trend (*see Table 7 for the growth trend of the oil industry in Alberta*). See Section 3.3.3.1 for a reference to the calculation of this factor.

2005		2008		2011		2014	
		31	1.018	67	1.009	103	1.002
		32	1.018	68	1.009	104	1.002
		33	1.018	69	1.009	105	1.002
		34	1.018	70	1.009	106	1.002
		35	1.018	71	1.009	107	1.002
		36	1.018	72	1.009	108	1.002
1	1.022	37	1.018	73	1.009	109	1.002
2	1.022	38	1.018	74	1.009	110	1.002
3	1.022	39	1.018	75	1.009	111	1.002
4	1.022	40	1.018	76	1.009	112	1.002
5	1.022	41	1.018	77	1.009	113	1.002
6	1.022	42	1.018	78	1.009	114	1.002
2006		**2009**		**2012**		**2015**	
7	1.009	43	1.006	79	1.005	115	0.998
8	1.009	44	1.006	80	1.005	116	0.998
9	1.009	45	1.006	81	1.005	117	0.998
10	1.009	46	1.006	82	1.005	118	0.998
11	1.009	47	1.006	83	1.005	119	0.998
12	1.009	48	1.006	84	1.005	120	0.998
13	1.009	49	1.006	85	1.005	121	0.998
14	1.009	50	1.006	86	1.005	122	0.998
15	1.009	51	1.006	87	1.005	123	0.998
16	1.009	52	1.006	88	1.005	124	0.998
17	1.009	53	1.006	89	1.005	125	0.998
18	1.009	54	1.006	90	1.005	126	0.998
2007		**2010**		**2013**			
19	1.017	55	1.011	91	1.006		
20	1.017	56	1.011	92	1.006		
21	1.017	57	1.011	93	1.006		
22	1.017	58	1.011	94	1.006		
23	1.017	59	1.011	95	1.006		
24	1.017	60	1.011	96	1.006		
25	1.017	61	1.011	97	1.006		
26	1.017	62	1.011	98	1.006		
27	1.017	63	1.011	99	1.006		
28	1.017	64	1.011	100	1.006		
29	1.017	65	1.011	101	1.006		
30	1.017	66	1.011	102	1.006		

Table 7 .- Monthly Alberta Oil Industry Growth Trend, separated by years, starting on July 2005 (1 value) and ending on December 2015 (126 value). (See section 3.3.3.1 for calculations of this data).

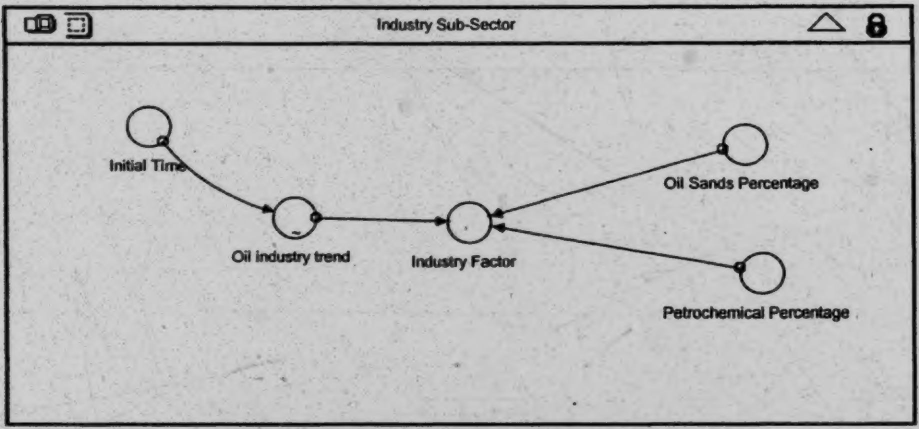
Industry Sub-Sector
Initial Time
Oil Sands Percentage
Oil industry trend
Industry Factor
Petrochemical Percentage

Figure 20 .- Industry Sector Diagram

4.4.3 Economy Sub-Sector

This Sub-Sector calculates the "Economy Factor" (*see Figure 21 for Economy Sector diagram*) by relating the markets of "Other National Industries" (the Canadian market without the Alberta oil industry), and "Worldwide Orders" (the international market), to economy trends. The economy variable suggested in section 3.3.3.1 to influence the company's sales was the exchange rate between CAD and USD. Thus, the "Exchange Rate Forecast" was related to the "Buying Decision National" by a percentage of the variation. This relation means that any change in the exchange rate will be reflected in the sales of "Other National Industries." In addition, the "Initial Time" value and an "After Forecast Exchange Rate" were set for simulation purposes.

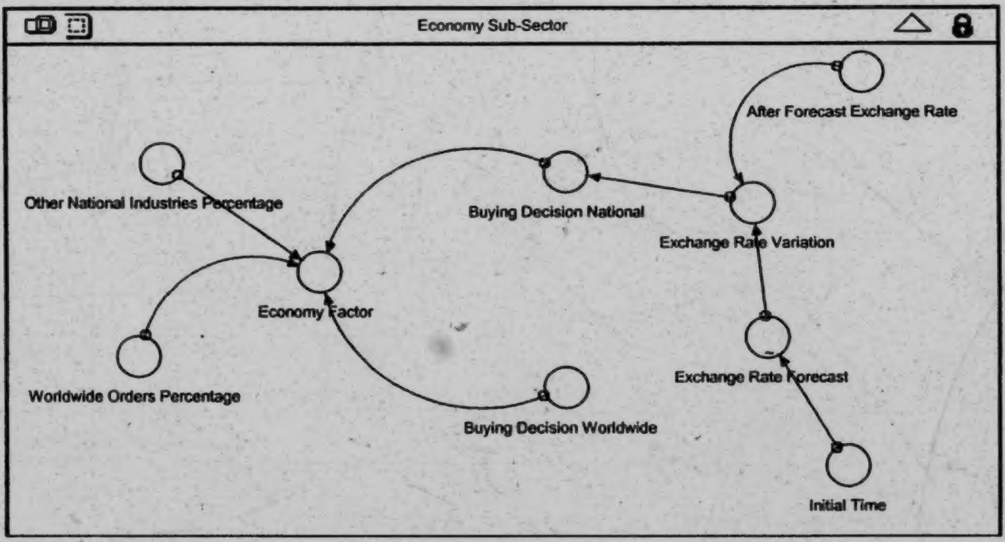
Economy Sub-Sector
After Forecast Exchange Rate
Other National Industries Percentage
Buying Decision National
Exchange Rate Variation
Economy Factor
Worldwide Orders Percentage
Exchange Rate Forecast
Buying Decision Worldwide
Initial Time

Figure 21 .- Economy Sector Diagram

The real values were used for the exchange rate until December 2005. The values from January to June 2006 were a projection of the exchange rate, obtained by using a three-value moving averages forecast (*see table 8 for exchange rate forecast*). The remaining months of 2006 were filled with the Financial Forecast Center data (2005). The values for 2007 up to 2015 were filled with a Bank of Montreal forecast (2006), which indicates that the CAD value will continue rising up to an exchange rate of 1.05 CAD per USD in 2015. As well the "Buying Decision Worldwide" was not affected by the Exchange Rate because the company's sales in USD neutralized its effect.

Month/Year	Exchange Rate CAD per USD	Month/Year	Exchange Rate CAD per USD
Jun 2005	1.24		
Jul 2005	1.22	Apr 2006	1.12
Aug 2005	1.20	May 2006	1.12
Sep 2005	1.18	Jun 2006	1.10
Oct 2005	1.18	Jul 2006	1.11
Nov 2005	1.18	Aug 2006	1.12
Dec 2005	1.16	Sep 2006	1.10
Jan 2006	1.16	Oct 2006	1.12
Feb 2006	1.14	Nov 2006	1.11
Mar 2006	1.13	Dec 2006	1.11

Table 8 .- Exchange Rate CAD per USD, starting on June 2005 and ending on June 2006. (Source until December 2005: Bank of Canada, 2006).

4.5 Final Results – Graphs and Tables

After the model was made, the simulation was carried out. The first question after the simulation was which variable would be the reference for the analysis. After a meeting with the manager of the company, it was determined that "Sales" was the main factor to be taken as a reference, since this variable most influences the company's survival. Moreover, it was discovered during the development of the simulation model that Sales influenced almost all the other variables. Thus, "Total Sales" as a monetary value, and orders ("Ordering Rate"), representing the volume of sales, were taken as references. (See section 3.3.3.3 for the validation of the simulation results.)

Another variable important to the company was considered to be the "Net Income," which was dependant on the "Total Cost." Moreover, if orders were going to be a meaningful variable, the "Awaiting Orders" had to be analyzed, since they determine if the customers are being supplied on time and will continue to order. Furthermore, the Cash availability ("Cash") and behavior of "Receivables" and "Payables" had to be monitored to guarantee the company's survival.

Once the main variables had been determined, tables and graphs were made, so that the simulation results could be presented in an organized way. The tables numerically show the data series generated in the simulation, while the graphs provide a way to analyze the trends and to compare the behavior of the different variables. These graphs and tables were generated by the Stella software, based on the variables' results from the simulation. The interpretation of these results will be presented in Chapter 5.

The first table with its respective graphs is the "Analysis Table" showing the company's 2006 projected behavior (using January data) in "Total Sales," "Total Costs," and "Net Income." *See Figure 21 for the tables and graphs of sales, cost and income.*

The "Analysis Table" and its graphs, which represent the base run for the analysis, reveal a steady increase in sales with a corresponding increase in cost and income. The first 6 months, which correspond to the first year, show a similar pattern as the same period in the second year, but the latter shows a lower sales level. Therefore, a cyclical behavior with a yearly upward trend is clearly identified. This cyclical behavior also shows that the year's first quarter had a decrease in sales and that during the summer months, the trend changed to rise but was not necessarily sustained during the rest of the year, as is shown in the results for second year. This behavior is due to weather conditions, since plant construction does not occur during winter time and is more intense during the summer.

Sales
Income
Cost

Figure 22.- Analysis Table and Graphs – Sales, Cost and Income (in CAD)

If we consider more years to reflect the external influence on the company's behavior in the long term, a stable oscillation of sales with a growth trend in the first two years and a smooth decline over the years can be observed (*See Figure 23 for a graph of simulated sales over the next 7 years.*) This decline reflects the lower level of the planned construction of extraction plants in the long run and can change over the years if more projects are created.

The results of this base model run were based on the assumption that no changes would occur in the whole set of variables (for example, an increase in the production capacity), and that the market would continue to follow the same pattern as analyzed in the last two years. Moreover, it represents the industry trends based on the committed projects only and not in a forecast. A yearly update to ensure the accuracy of the model's results is recommended.

Figure 23 .- Graph of simulated sales over the next 7 years starting in January, 2006

The next table analyzed is the Financial Information Table, which includes the cash availability and the behavior of "Receivables" and "Payables." Graphs are also provided for each of the variables to provide a clear perspective. *See Figure 24 for the tables and graphs of Receivables and Payables.*

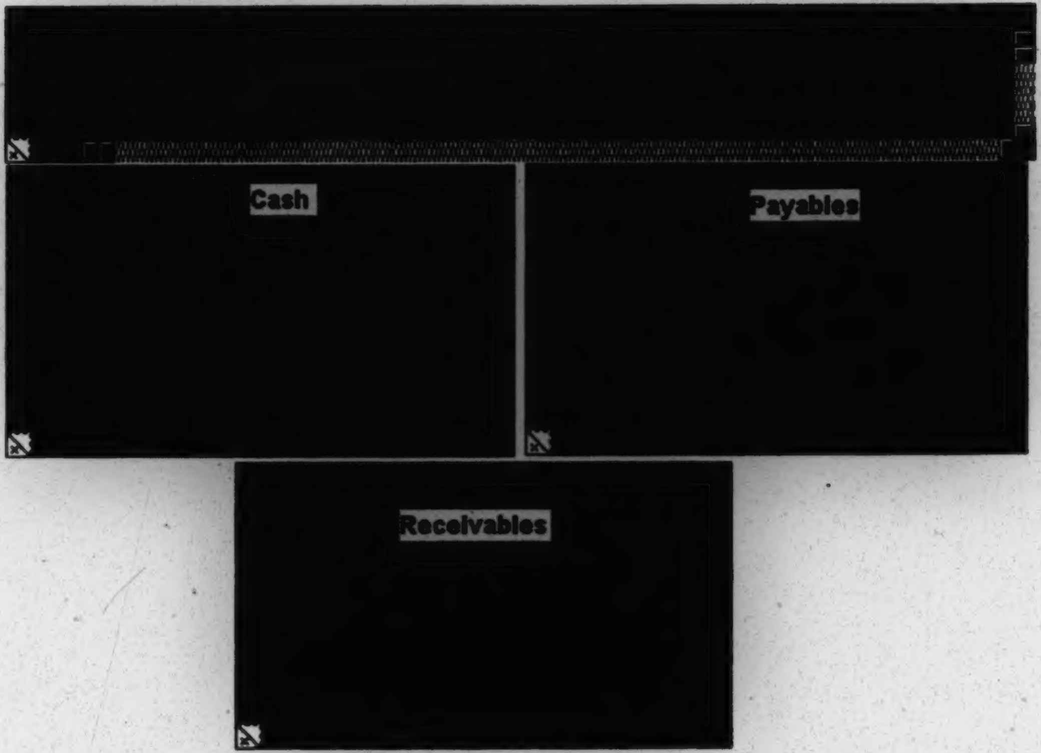
Cash
Payables
Receivables

Figure 24 .- Financial Information Table – Cash, Payables and Receivables (in CAD).

The tale and its graphs show that although the sales levels increased, the cash availability remained the same and just oscillated slightly. This result means that the cash availability is a fixed factor determined by the company's policy. However, this policy does not guarantee the cash availability for the company's growth. For example, if sales increase by 100%, the company will wait until enough cash is available to buy extra material from the suppliers, but this cash can never be obtained since the business runs on a smaller cash basis. Therefore, the cash policy should be based on the sales levels in the medium and long terms (2 years or more in the future).

For Payables, the table and its graphs show the same pattern as that for sales, meaning that Payables are paid on time on a monthly basis after they are generated when ordering supplies. The Receivables show a stable pattern like that of cash, meaning they are collected in a regular basis. Therefore, if the company's policies concerning payments and charging do not change, the cash availability will not be affected.

The "Ordering Rate" is the variable representing new sales in a non-monetary way, so it has to be monitored. The next table presents the ordering rate of every single product and special orders. They are also represented in a graph so that their behavior could be observed at the same time to determineif any one of them shows a different pattern. *See Figure 25 for the table and graph of each product Ordering Rate.*

The Ordering Rate shows a growing trend in all type of products, peaking at the end of the second year. The Ordering rate's rising trend makes the Awaiting Orders accumulate over time, so that a certain capacity will not guarantee the supply of products when sales overpass that level.

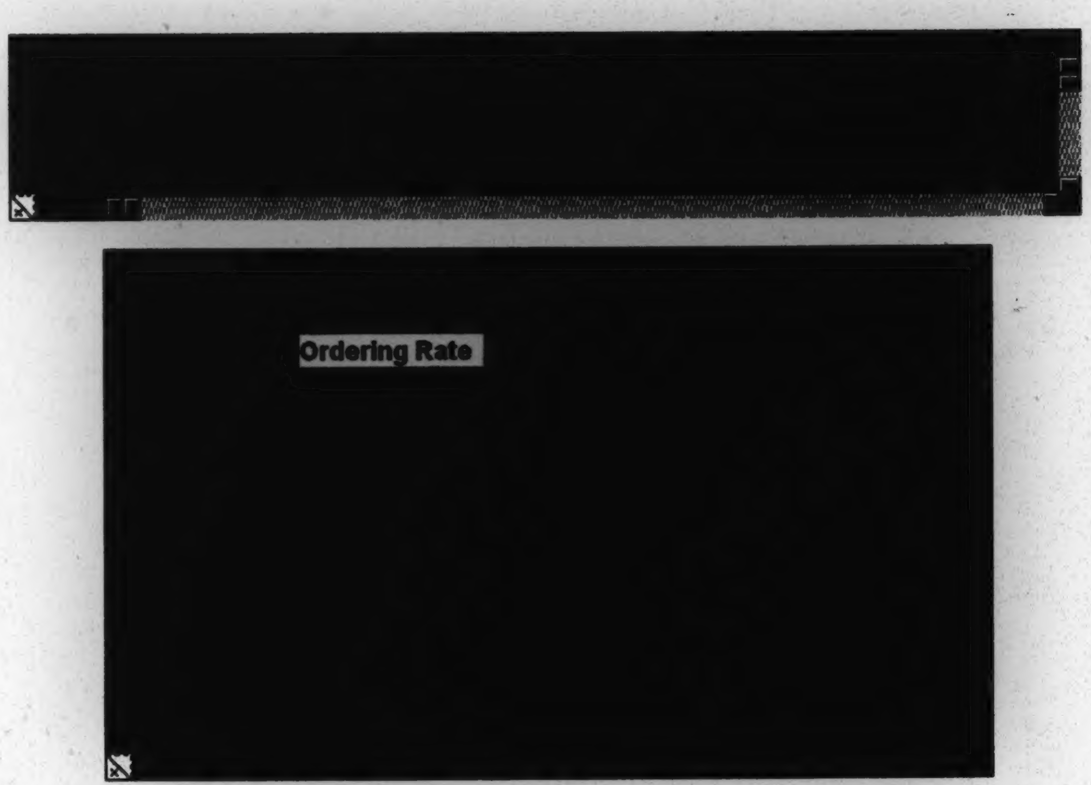

Figure 25 .- Ordering Rate from January of 2006 (6) to December of 2006 (18); Table and Graph.

The last table presents the results for Awaiting Orders, showing the awaiting orders for every single product and the special orders. Like Ordering Rate, the Awaiting Orders are represented in a single graph in order to compare their behavior. *See Figure 26 for graph and table.*

Once the simulation results were obtained and presented in the form of tables and graphs, a sensitivity analysis had to be used to perform a complete analysis of the company's behavior. As well, the model's usefulness for developing a PMF for a SME had to be demonstrated. These topics are explained in the next chapter.

4.6 Limitations of the Model

The following are some limitations of the simulation model:

- The model was designed only to represent the behavior of the specific company analyzed. To apply the model in another company, even in the same industry, it has to be adapted.
- Sales growth projections were based on committed construction of oil extraction plants, so they do not represent a forecast, since more construction can be planned in the future.
- Exchange rate forecast is based only on the cited source, and relies on the accuracy of it.
- The model was designed to perform a sensitivity analysis and to support the definition of the company's drivers and goal-setting, as well as to support a company's PMF. Nevertheless, it cannot be used for other purposes without a previous review.
- Internal operation factors were determined based on management judgment and the company's policies, but only financial information was taken into account.

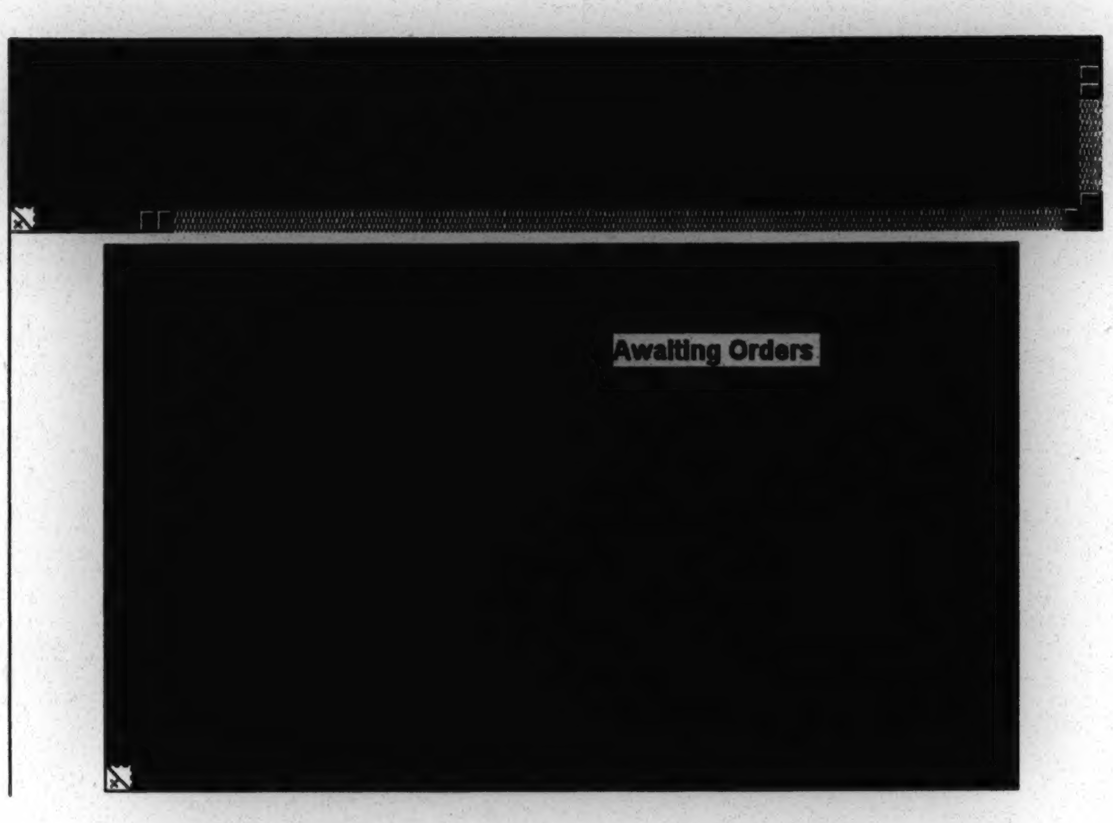

Figure 26 .- Awaiting Orders from January 2006 (1) to December 2006 (18); Table and Graph.

Note: the y axis shows the number of orders.

Chapter 5 - Analysis of Results and PMF development.

5. 1 Introduction

After the simulation model performed the results had to be analyzed in order for it to be useful for the purposes of this study. These results were first analyzed by using graphs and tables. After this first approach, a sensitivity analysis was performed by changing the main parameters in a proper range to study the company's simulated behavior. This analyzed behavior identified the company's main factors or "drivers" which could be used to evaluate the probability of developing a measurement system. Furthermore, the manager's comments were used to evaluate the different parameters changed at his request and to help predict the company's future behavior. All these topics are discussed in the next sections.

5. 2 Overall Behavior of the System

5.2.1 Sensitivity Analysis

The sensitivity analysis was carried out by using two approaches: (1) Internal input data manipulation and (2) External factor changes. During the manipulation, the internal input variables were changed, such as Price, Payables Policy, Receivables Time, Number of Workers, and Productivity (under a pull system process, the maximum capacity that is reached when clients' orders are high). The second approach was used to analyze the impact of a variation in the external factors such as Sales (represented as the ordering rate), Costs, Exchange Rate CAD per USD, and Industry Trends.

It was decided to monitor the simulated results in Sales, Cost and Income of 2006 in the different scenarios analyzed. Each variable was changed to be lower and higher than the original value in different percentages, and the results were compared with the original ones.

The impact of each variable was determined by the standard deviation of the accumulated results (year sum), of sales or income. If it had a standard deviation of more than 0.30 (over the average value), it was considered to be a driver.

5.2.1.1 Internal input variables analysis

The first input variable analyzed was the Price. This variable includes the whole set of prices for the different products of the company, so the expression 110% of Price refers to a 10% increase in every single price (Price 150, Price 300, Price 600 and Price SO). *The simulation results of the different Price values are shown in Table 9.*

Table 9 reveals that raising the price should not be recommended since the price has a great impact on sales. On the other hand, lowering the price can generate more sales that can compensate for the decrease in income and even generate more. The analysis shows that a 10% decrease in price results in the best sales increase (*See Figure 27 for a price level comparison graph*). Moreover, due to the great impact (0.60 standard deviation) of the price on the sales level (as shown in the simulation results of *Table 1 in Appendix 7*) the price can be considered a “driver” of the company and must be controlled.

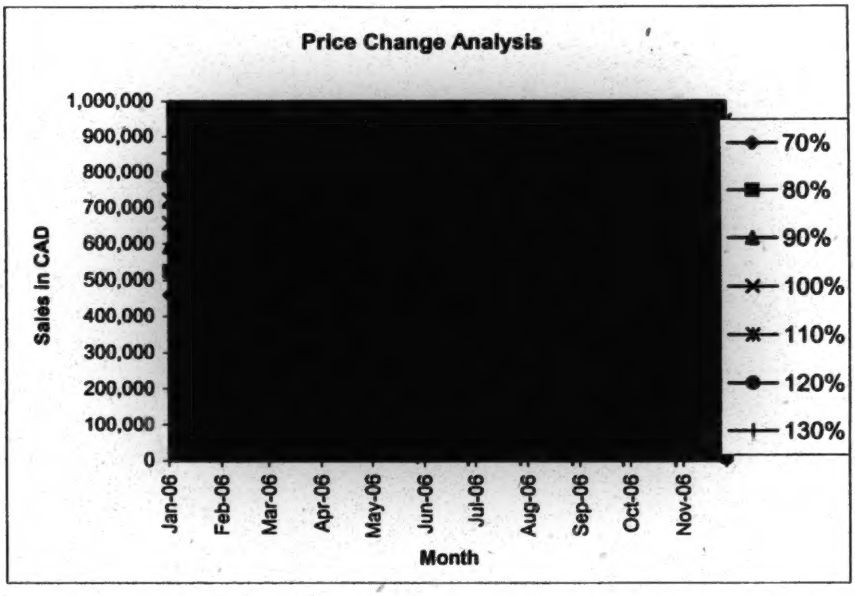

Figure 27 .- Price level comparison graph.

The second input variable analyzed was the number of workers in the shop floor (*See Table 2 in Appendix 7 for the workers in the shop floor simulation table*). This variable does not seem to have a significant impact on sales (0.13 standard deviation) but changes the cost levels due to salaries (*See Figure 28 for the graph on the number of workers sales impact over time*). Thus, it is not recommended to change the number of workers, at least, not in the short term. However, considering the company's growth trend, an increase in the number of workers in the long term can be considered. Further yearly simulation analysis will be necessary to determine the appropriate time to increase the number of workers.

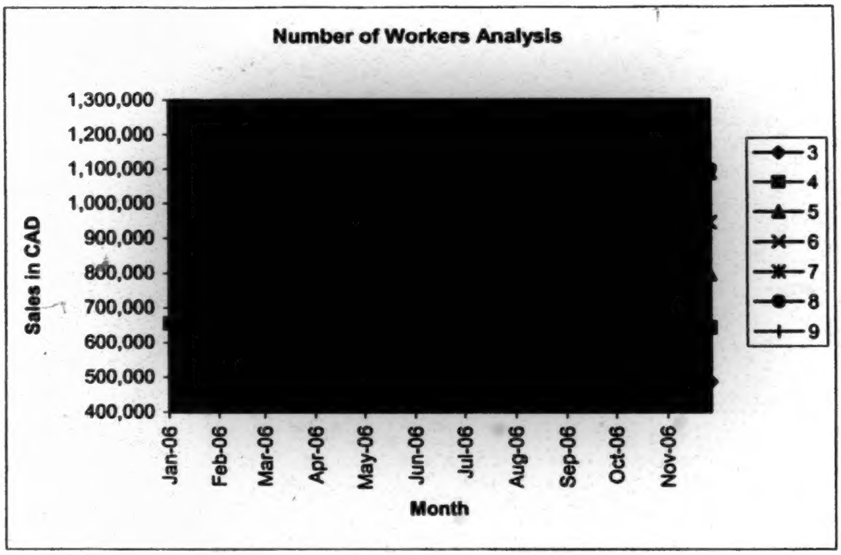

Figure 28.- Number of workers sales impact over time

The third variable analyzed was productivity, specifically the company's maximum monthly capacity. Measuring productivity is a difficult task in this company due to the lack of information, the different prices of the products (valves), and the different volumes produced (the bigger the valve, the less are produced in a given period of time). Since the only historical information available is the financial information, it had to be used to calculate the productivity. In the simulation model, "productivity" was defined as the number of valves produced by each production worker. In accordance with this definition, the Total Sales (in CAD) was divided by the number of workers to determine how much each worker produced on a monetary basis. Next, the production monetary value was divided by the average price of the different products, to determine how many pieces at an average price were produced by each worker. Even if this factor does not show the exact number of each type of valves produced, it can be used in the simulation as a reference for analysis.

Considering that the maximum capacity observed in the two years of data is of 20 average-price pieces (valves) per production worker per month, this figure can be considered as the peak of the current capacity. Thus, the analysis was carried out by using 20 as a maximum (*See Table 3 in Appendix 7 for the productivity simulation table*).

In the company, it is assumed that enough capacity is always available to produce every client's order on time. It is considered to be a pull system, in which any time an order is placed by a client, it is started its production. However, the simulation results suggest that in the long term, the capacity will not always be adequate and also that the maximum productivity level will not always be reached. Thus, Table 3 in Appendix 7 reveals how lower productivity levels (lower maximum capacity) can impact the yearly sales (*See Figures 29 and 30 for sales level graph due to production capacity*). Therefore, productivity is one of the variables that must be monitored over time, and maximum capacity is a limit to growth that might change in the long term. This finding is in accordance with the number of workers analysis, so these two variables should be monitored at the same time.

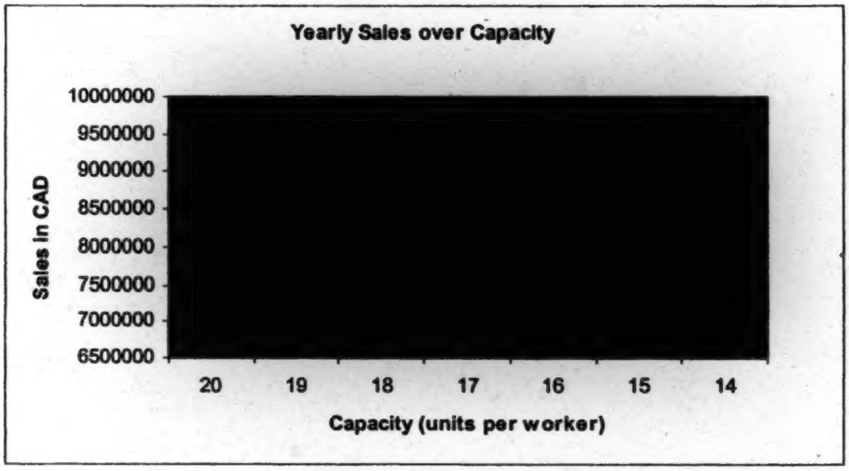

Figure 29 .- Yearly sales level due to production capacity.

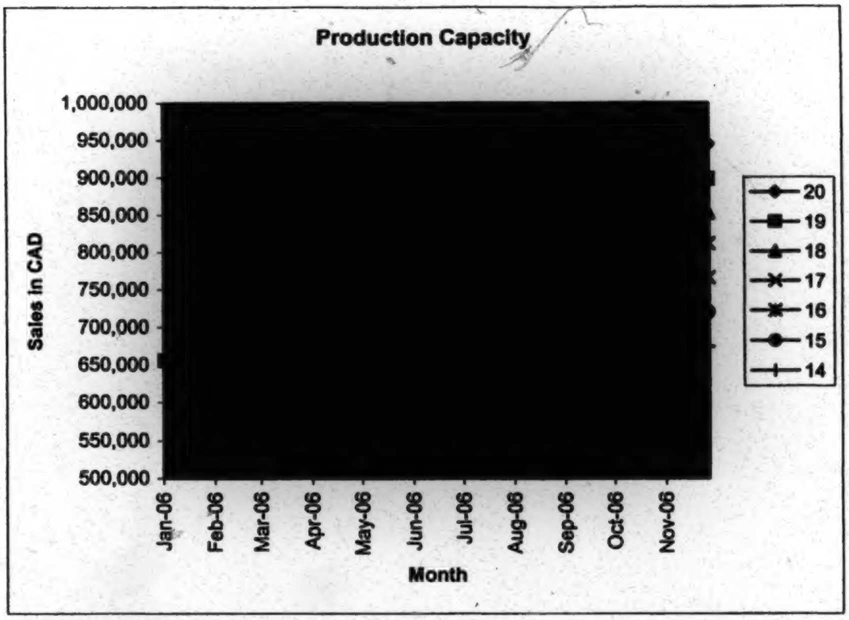

Figure 30 .- Monthly sales level due to production capacity.

The other two input variables analyzed were the "Payables Policy" and the "Receivables time." These two variables showed no impact on sales, compared to the findings in the previous study (Ali, 2003). However, if the Receivables are not collected properly they can impact the cash availability, but only in the long run (i.e., 10 years or more) and can result in a supplies deficit.

5.2.1.2 External variables analysis

The first external variable analyzed was the sales level. Since this variable depends on the interaction of the whole set of factors taken into account in the simulation model, it was decided to analyze it by using an increasing or decreasing factor (as a monthly percentage). Therefore, this analysis determined how the sales department's efforts would affect the company's performance measured as income level (*See Table 4 in Appendix 7 for Sales variation simulation results*).

The simulation results reveal that income will decrease by 50% for every 10% decrease in the sales levels. On the other hand, an increase in the sales levels does not show the same ratio. The first 10% of a sales increase can have a great impact on the income level. Therefore, as an incentive, bonuses could be paid to salespeople who increase the sales level by 10% or more monthly. Furthermore, the results showed the sensitivity of this factor (0.64 standard deviation) and confirmed it is a driver of the company (*See Figure 31 for a graph on monthly sales level due to sales factor variation*).

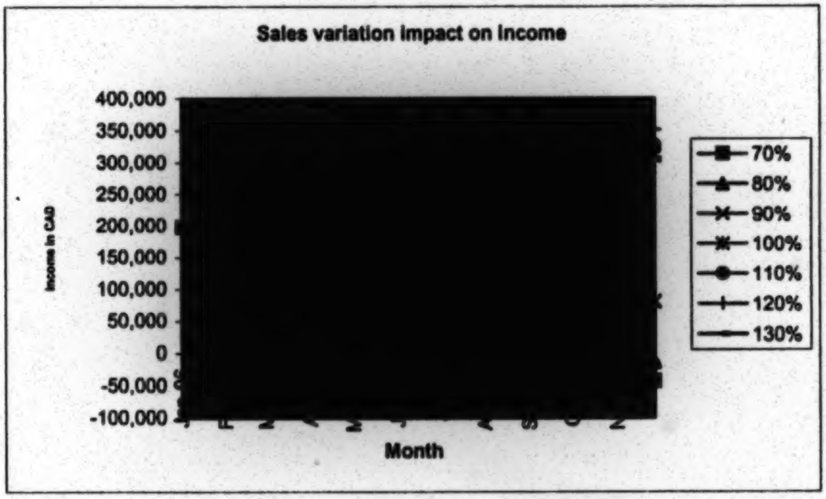

Figure 31 .- Monthly sales level due to sales factor variation.

The second external variable analyzed was the "Total Cost." Since this is another variable that depends on the interaction of many other factors, a monthly percentage of this variable's increase or decrease was simulated and its impact on the income level was analyzed (*See Table 5 in Appendix 7 for Cost Variation simulation results.*)

It was determined that the cost factor has a direct effect on income (0.53 standard deviation). In addition, the cost can affect the pricing decisions, but only if it is increased permanently and in the long term (10 years or more). Therefore, it is recommended that this factor, which when reduced, can directly generate more income, should be monitored (*See Figure 32*) Nevertheless, the simulation model did not consider other variables, such as the quality of the product, that might be changed when reducing cost and that at the same time can reduce sales.

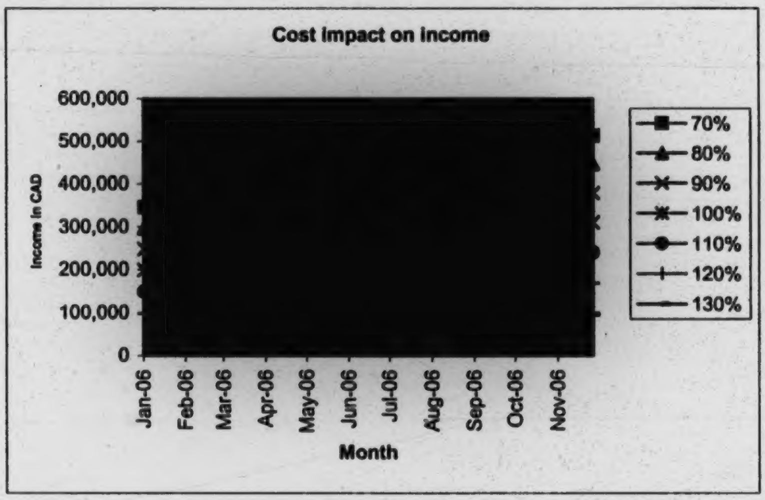

Figure 32 .- Monthly cost variation impact on income levels.

The third external variable analyzed was the exchange rate CAD per USD. As with the other external variables, the analysis was carried out by manipulating the values as a monthly percentage (*See Table 6 in Appendix 7 for Exchange Rate variation simulation results*). In the case of the exchange rate, the analysis found an unpredicted change that was not contemplated in the forecast.

The exchange rate variation analysis revealed that the exchange rate has a very low impact (0.001 standard deviation). This finding is reasonable since the exchange rate impacts mainly the "other national industries sales," which represent only 9% of the overall sales (*See Figure 33 for a graph of the Exchange Rate monthly variation impact on sales.*) Moreover, international sales are not affected either since they are paid for in USD so that the effect of the exchange rate is eliminated. Therefore, the exchange rate does not need to be monitored every month, only for the medium-term trends (5 years or more).

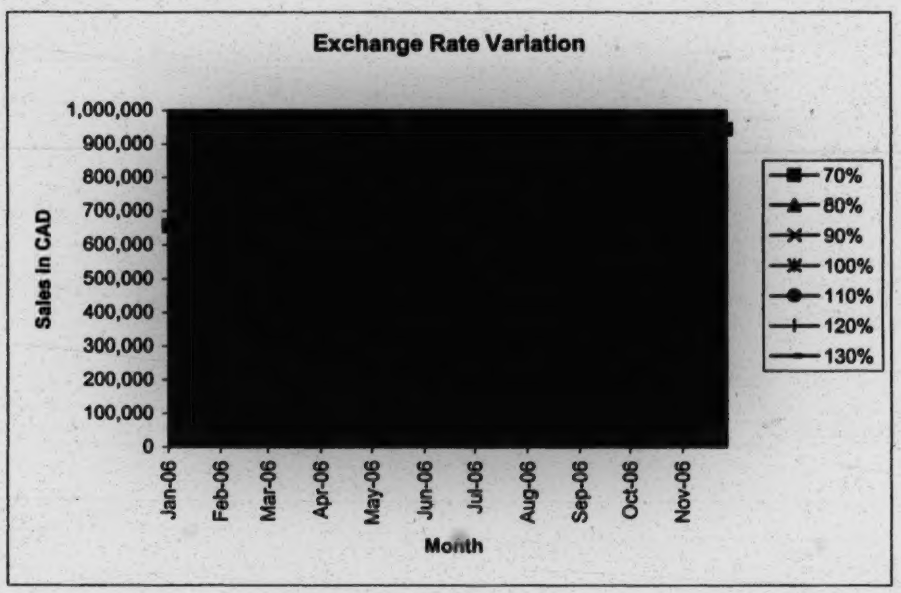

Figure 33 .- Exchange Rate monthly variation impact on sales.

The last external variable analyzed was the Industry factor. The analysis was carried out by modifying the variable as a monthly percentage (*See Table 7 in Appendix 7 for Industry factor variation simulation results*). The results show that the industry trends have a considerable impact on the company's sales (0.36 standard deviation) (*See Figure 34 for a graph of the Industry monthly trends' impact on sales.*) However, since the industry requires major investments to grow, it is stable enough not to experience dramatic changes. Therefore, the Industry Factor needs to be monitored only in the long term.

In the short term, the current growth projections of the industry can be analyzed and they will be a good basis for making forecasts. In the model, these projections are simulated by using the current plant development trends to project a monthly growth to meet the expected annual growth.

The represented behavior of the industry trends make sense in reality, since even when oil prices are high, the new plant constructions are planned for many years in the future and can be monitored in the suggested period of time. Additionally, if the model is updated every year, it will show every change in future plans.

After completing the sensitivity analysis of the input and external variables, feedback had to be obtained from the company's management. The manager's observations when using the model are presented in the next section.

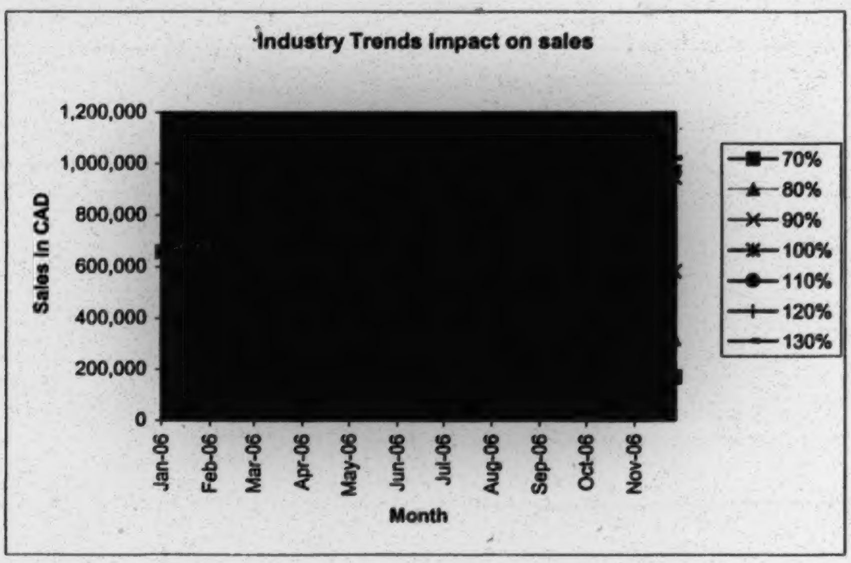

Figure 34 .- Industry monthly trends impact on sale.

5.3 Manager's Opinion of the Simulation Model

During the process of developing the simulation model, the company's management was contacted several times to obtain feedback. Even after the model had been completed, it was modified in response to the opinions of the people contacted. Thus, the final model was the result of improvements made after management revisions. These modifications are explained next.

When the completed model was presented to the company's management, the comments were

1) Did the simulation model include the sales effort to increase orders?

2) Could the simulation model be updated up to the last month?

3) The sales trends were too optimistic.

4) How useful was the simulation model to the company?

5) What software was necessary to use the model? How much did this software cost? Could it be installed in the company's network?

6) Several other factors influenced the business besides the ones simulated, so the model's validity was questionable.

In order to respond to all the comments, the model was modified, and all the questions were answered. The results obtained (in the same order as the feedback comments) were the following:

1) It was decided to not modify the model itself, but to include in the analysis the possibility of sales variations in different percentages (see section 5.1.3.1) in order to observe the company's behavior when sales either increased or decreased.

2) The simulation model was updated to include data up to December of 2005 so that the entire year 2006 could be simulated (the first model started in the month of June of 2005).

3) The simulation model was adjusted to include another external factor called the "Sales Factor," which accounted for an additional variability due to normal cycles in clients' orders. In other words, it was discovered that the model included only the sales variation generated by the variables simulated, but it had not considered that sales vary over time due to different clients' needs. The basis for the new factor was the variability of the historical data available for the analysis (See section 4.4.1).

4) The manager's concerns about the simulation model's usefulness were addressed by mentioning the model's ability to forecast the company's behavior over time, based on the company's current policies and operations. Therefore, this model could be used to analyze how current decisions would influence the company's future quantitatively. As well, it was explained that the sensitivity analysis based on the simulation results, had identified the "drivers" of the company. With such drivers identified, a PM system in which these key variables could be monitored and improved could be built (See section 5.4.) The manager's concerns about usefulness did not generate a modification of the model.

5) The software "Stella" was introduced to the manager, and a budget was presented that includes the possibility of government financial aid. Furthermore, the possibility of contacting the person in charge of the company's computer systems, asking him to install the software in the network, and training him to be able to operate it in the future was mentioned. However, it was decided to postpone the acquisition of the software since the

company would receive the first year's analysis anyway and could contact the university if additional information was needed. This comment did not generate any modification.

6) It was mentioned that in the SD theory on which the model is based, studying the overall behavior of a system (the company in this case), is more important than trying to study details (See section 2.5.2.1). Therefore, the variables and factors included in the model represented the company's overall behavior based on the historical data, and sometimes did not include details on why the company behaved as it did. It was also mentioned, that the results from the simulation were tested for validity by comparing them with the historical data, and showed the same behavior as well as the expected growth trends. This comment did not generate modifications to the model, but was helpful for verifying the validation process.

After an improved model was created in response to mainly the manager's first 3 comments, the complete analysis presented in section 5.2 was carried out and was presented to the company. In addition, the possibility of developing a PMF based on the information obtained by the SD simulation was analyzed. This analysis is presented in the following section.

5.4 Developing a PMF for a SME

The following explains how some of the issues identified in Chapter 2 were addressed by this model:

1) Due to the kind of historical information limitations that characterize most SMEs, the different variables for measuring had to be obtained from the financial system.

Later, the variables were increased to include more internal information based on management experience and to also include economic and industry trends information (Section 3.3.3.1).

2) All the data available for the different variables obtained were collected, and used to feed the simulation model. In the simulation, these variables eliminated the need to establish time and cost-consuming measuring activities based on the company's regular operations. In addition, the variables could be manipulated, and their impact on the company's results in the short and long terms could be foreseen. See Chapter 4 for a complete description of the simulation model.

3) The simulations carried out by the sensitivity analysis identified the company's key "Drivers" as Price, Sales levels, and Cost. The cost has to be carefully monitored since it might impact the quality of the products. The analysis suggested that the impact on the industry trend was stable enough to eliminate the need to monitor it monthly. On the other hand, the number of workers in the long term might be an important issue when the maximum productivity per worker is reached. See Chapter 5 for a complete discussion of the analysis.

As was discussed in section 2.2.1, a PMF could help the company to determine how well its organization is performing and to help it to decide what it should do next (Neely, 1998). In other words, a PMF involves not only a measuring system, but also the actions taken in response to the measurements. Therefore, the goals for each of the variables and the actions taken to achieve these goals should be clearly defined.

It was decided to define the first year's goals and to let the company's management to decide on what actions to take to achieve them. Thus, the results from the sensitivity analysis can be used to identify the following specific goals:

1) Price: 0% increase in normal price (including USD prices). In addition, a top 10% discount program carried out by salespeople (with respect to the original price).
2) Sales levels: 10% increase in sales level monthly
3) Cost: Since the cost was shown to impact income, a decrease in the total cost (with respect to the projected cost) is suggested. This decrease can be achieved by reducing the scrap rate, which is currently 1% of the total production.

In order for this PMF to be implemented properly, it should be monitored monthly by the company's manager to determine the effects of the actions taken. In addition, it is suggested that the company should create a yearly plan by using the simulation model with updated data, and by setting specific goals. To help with this planning, a "Goal Monitoring Table" could be used. (*See Figure 35 for an illustration of this table.*) In such a table, each variable is written in each row, and each month's goal that will be necessary to meet the yearly goal is listed. As well, a row can be used to register the real results obtained each month (or the actual value) for comparison. If the goals are not being met, the company can take corrective actions to solve the problem identified by Bititci, et al. (2000), who found that the current PMFs do not include a loop for control including corrective actions.

Goal Monitoring Table

Variables	Months:	January	February	March	April	May	June	July	August	September	October	November	December	Yearly Goal
Price Increase	Actual													
	Goal	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Discount policy	Actual													
	Goal	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Sales	Actual													
	Goal	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Cost	Actual													
	Goal	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%

Figure 35 .- Goal Monitoring Table

If a goal has not been achieved, a table can be used to register the corrective actions taken (*See Figure 36 for Corrective Actions Sheet*). This table can indicate who is responsible for the implementation, the month in which it was discovered that the goal had not been achieved, the variable involved, the real (actual) result obtained, the original goal, and the difference between the actual result and the goal. After registering all the general data, the manager can indicate the corrective actions that will be taken.

Corrective Actions Sheet	
Responsible:	
Month:	
Variable:	
Actual Value:	
Goal:	
Difference:	
Corrective Actions	

Figure 36 .- Corrective Actions Sheet.

Chapter 6 - Conclusions

6.1 Summary of conclusions

SD methodology proved to be useful for developing a PMF for a SME for Decision-Making. This methodology helped to explain the complex behavior of the business, which has a large number of variables. Moreover, the methodology was used to develop the measuring systems by defining the key variables or "drivers" that have a great influence on the business performance. Furthermore, the methodology was used to define some goals for the company, by providing specific data generated by the simulation model.

This study also demonstrated that by using SD, the current PMFs could be improved to include characteristics such as dynamic ability, flexibility, conciseness, clarity, maintainability, and ability to forecast the future performance. The simulation was based on the financial information but also included the effect of external influences. All these characteristics were identified in the literature review as being necessary for a PMF due to the specific behavior of SMEs and due to the current PMFs' deficiencies.

Furthermore, it was demonstrated that the difficulties of applying a PMF in a SME could be overcome if the SD methodology were used and if it were complemented by the use of external data. Although the study achieved its stated purpose, the model needs to be enhanced to include more management systems such as the Quality Management System.

6.2 Contribution Of The Study

The research had as a specific outcome, a SD computer simulation model of the behavior of an Alberta manufacturing SME, and the model's application in developing a PMF. This model is capable of reproducing the dynamic behavior of the internal and external systems in the company analyzed.

The model presented satisfied the requirements to be based on the financial measures of the company, to integrate the production and sales systems, and to include the influence of the industry sector and the economy. Moreover, the model can be easily expanded to integrate new management systems, since it includes simple links between the internal and the external systems. As well, the PMF based on the model proved to be a useful tool for supporting management decision-making.

Furthermore, the simulation model overcame the identified deficiencies of the previous study's model (mentioned in section 1.2), such as:

- The incorporation of just one external factor (oil price). The new model integrated the industry's and the economy's influences as separate subsystems with their own behavior and factors.
- Special Orders needed to be considered as an independent system. Nevertheless, it was decided that this problem could be avoided by analyzing the behavior of the company as a whole over a greater period of time.
- Three months of data were not enough for a proper analysis. Therefore, two years of data were used.

- The new model identifies a cyclical behavior during each year, while the previous model assumed that the data for the whole year would be the same as the data available for the three months.
- The previous study did not include a feedback loop analysis of the model's behavior. In the present study, the simulation model was based on the feedback loop analysis itself.
- Management did not provide any feedback on the computer simulation model's results. In the current research, management was consulted many times so that the expertise provided by the feedback was useful to improve the simulation model and its results.

6.3 Recommendations For Future Development

As previously discussed, the model does not cover important aspects of a PMF such as other management systems like the one for Quality. To include them, more research on companies that already have formal management systems set in place needs to be carried out so that the model can not only be expanded, but can become a generic PMF for manufacturing SMEs.

Other management systems that can be included that were not mentioned before are

- The Environmental Management System
- The Organizational Health and Safety Management System
- The Social Responsibility Management System

These management systems can be included in the simulation model by adding a whole sector for each one and relating them to some relevant variables. For example, each of them can be related to the "External Factor" by determining their impact on sales and including this effect in the variable. Other relevant variables can be identified by verifying the impact of each of the management systems on each variable in the other sectors and by developing links among each of the sectors involved. For example, the environmental management system can include a waste reduction variable that makes the scrap rate to decrease so that the production sector can include a linking variable between the scrap rate and waste reduction.

Including those management systems, plus the already mentioned QMS, in a single model can be helpful for the development of a PMF that will aid in the integration of management systems so that the management systems are not isolated from each other and do not generate decisions that can be contradictory. With integrated PMF, the overall business performance can be measured, and only those decisions that benefit the entire company will be made. For example, the cost of waste can be reduced, supporting a company's environmental policy and even improving the quality of the company's products.

The SD simulation model generated can also be used to improve the current PMFs, so that the expertise generated from the use of those systems can be utilized for better results. Furthermore, the use of SD can reduce the resistance to change when a system is already in place.

Finally, for the simulation model to be useful for supporting the proposed PMF, this model has to be updated and continually used. Doing so requires management commitment. Therefore, further research could be carried out on a PMF's permanent implementation and the follow up.

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Appendices

Appendix # 1

Survey

Company Profile

Name of interviewee: ______________________________

Name of the Company: ______________________________

Address: ______________________________

City: ____________________ Province: ______________________

Postal Code: __________ Phone: ( ) ____________ Fax: ( ) ____________

Type of Company: Manufacturing / Service

How many years your company has been in business? ____________________

What were the gross sales (Revenue) of the company last year? ____________________

Number of current employees in the company Full Time ____________________

Part Time ____________________

How is the ownership made up?

___ Sole proprietorship

___ Partnership

___ Incorporated

Operations

Describe the production process: ______________________________

____

____

____

Products and Ordering

Who are your major customers, and what products do you provide them? ____________

____

How do you categorize your products – as a service, as product lines or as product families? Which are they, and what percentage of the business does each represent?

____

____

____

Describe the ordering system: ______________________________

____

____

____

List all types of products: ______________________________

____

____

Are there any seasonal orders? If yes, describe the different periods: __________

____

____

Does the economy impact your orders? Yes / No

If yes, what is the relationship? __________________________

____

Does a delay in service or delivery affect orders? Yes / No

If yes, what is the relationship? __________________________

____

Does the cost (of product or service) affect orders? Yes / No

If yes, what is the relationship? ____

____

____

Does any other factor affect orders? How?

____

____

____

Personnel

What is the total number of employees? ____________________________________

How many of the employees are involved in the production system (shop floor employees)? ____

What is the average time to train an employee? ____________________________

What is your employee turnover rate in Production and in Administrative departments?

____

____

____

Does employee turnover affect the production rate? ______________________

Explain: ____

____

Which other factors are affecting the personnel? How? ____________________

____

____

Manufacturing and Production

How does the company process an order? ______________________________

____

____

How do you calculate your production rate? ____________________________

____

____

What is the range of lead-times from order to delivery? ____________________

What is the dollar/percentage of the following types of inventory?

Raw Materials? $ ______________ ________________ %

In Process Materials? $ ______________ ________________ %

Finished Goods? $ ______________ ________________ %

What is your scrap rate? ____

What is your rework rate? ____

How is the scrap rate determined? __________________________________

____

How is the rework rate determined? _________________________________

____

What is the cost of scrap as a percentage of total operating cost? ______________

What is the cost of rework as a percentage of total operating cost? ______________

How do you calculate the productivity of a worker? _______________________

____

What is the ideal machine to worker ratio (or jobs/worker) ? ____________________

____

If using machines, what is your machine failure rate? ____________________________

How long does it take to fix a machine (Maintainability)? ________________________

____

What is the monthly machine capacity? ______________________________________

What is the machines' setup time? ____

Does any other manufacturing factor affecting the process? How?

____

____

____

Selling

How is selling (service / products) performed in your company? __________________

____

____

____

What is the effect of delivery delay on selling? ____________________________

____

____

____

Does any other effect impact selling?
How does this effect impact the company operations?

____

____

Financial

How do you calculate your company revenue?

How do you calculate your production cost?

What is your cost of selling your products and/or services?

What were your gross sales for the last fiscal year?

What has been the trend of gross sales for the last two years?

What was the profit margin last year?

What has been the trend or your return on sales over the last two years?

What is the average salary per employee?

What is your overall overhead cost?

Does any other factor influence the financial standing of the company? How?

Marketing and Promotion

What techniques do you use to promote and sell your products and / or services? ______

____

____

What is your average promotion spending (per unit) ? ________________________

Does promotion have any effect on getting orders? __________________________

____

____

____

Does any other factor from marketing affect the company's operations? How?

____

____

____

Reference:
Survey adapted from: Ali, I. (2003) "A Performance Measurement Framework for a Small and Medium Enterprise". Master of Science Thesis. University of Alberta.

Appendix # 2

Survey 2 - Extra Questions

1) Do the workers, after finishing all the orders for one type of valve, continue working with other types of valves?

____

____

____

2) Can any pattern be observed in how Special Orders behave? Do you have any data on this issue?

____

____

____

3) Do any Add Ons to the valves change significantly the price and consequently the profit obtained from them? How do any Add Ons influence the total revenue of the company?

____

____

____

External Factors

-Clients Factor, Overseas Competition, Industry Factor and Economic Factor

Questions:

1) Does any special valve drive the behavior of the company?

2) Where does a valve go after leaving the company? Is there any distributor? Is the client contacted directly?

2a.- If there is a distributor, how does it make its buying decisions? Is there any main client?

3) Is the major client related to the oil industry?

3a) If it is related to the oil industry, does the price of oil have any influence on sales?

4) Does the overseas competition have any influence on sales?

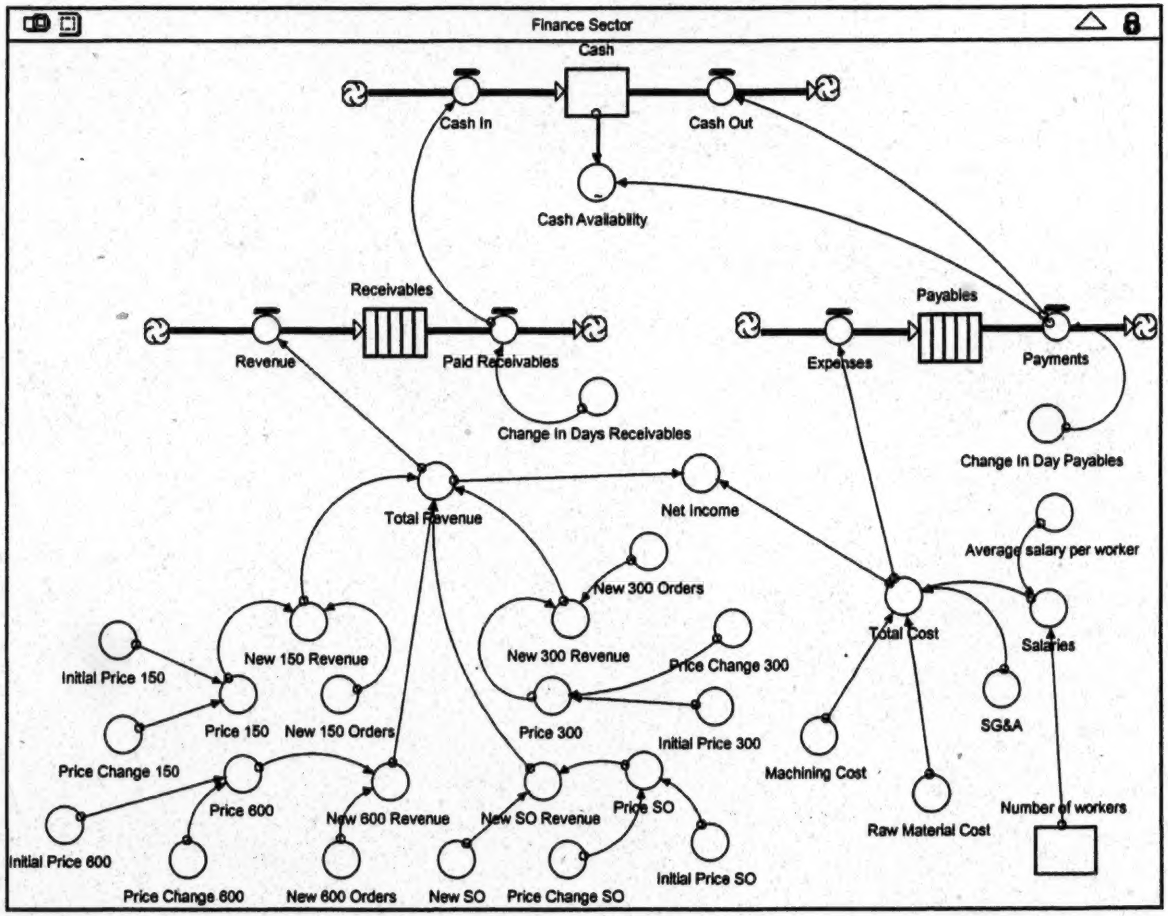
5) Does any other external factor affect sales in the company?

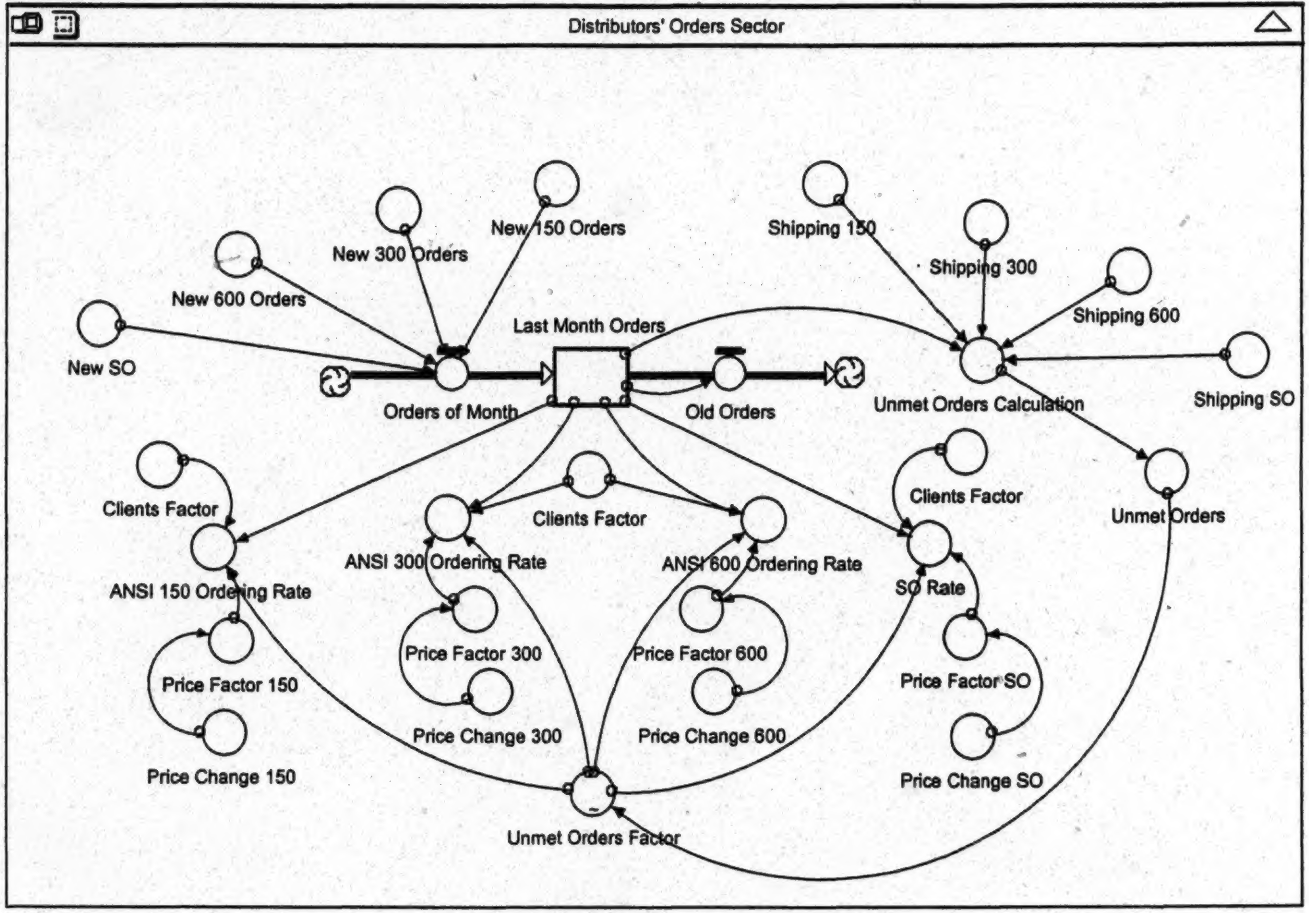
Output – Extra questions

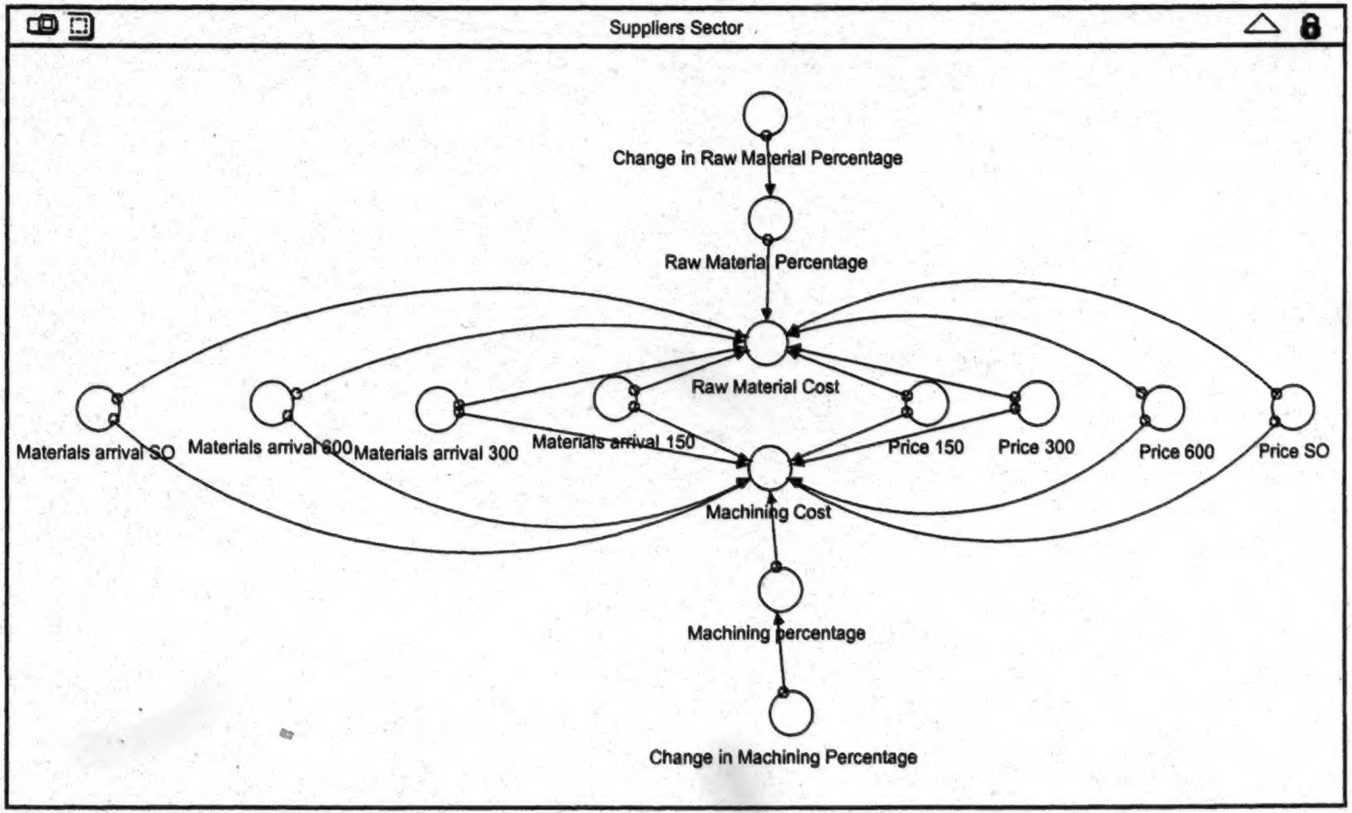
What would you like the model to show as a result? Are you interested in any particular variable?

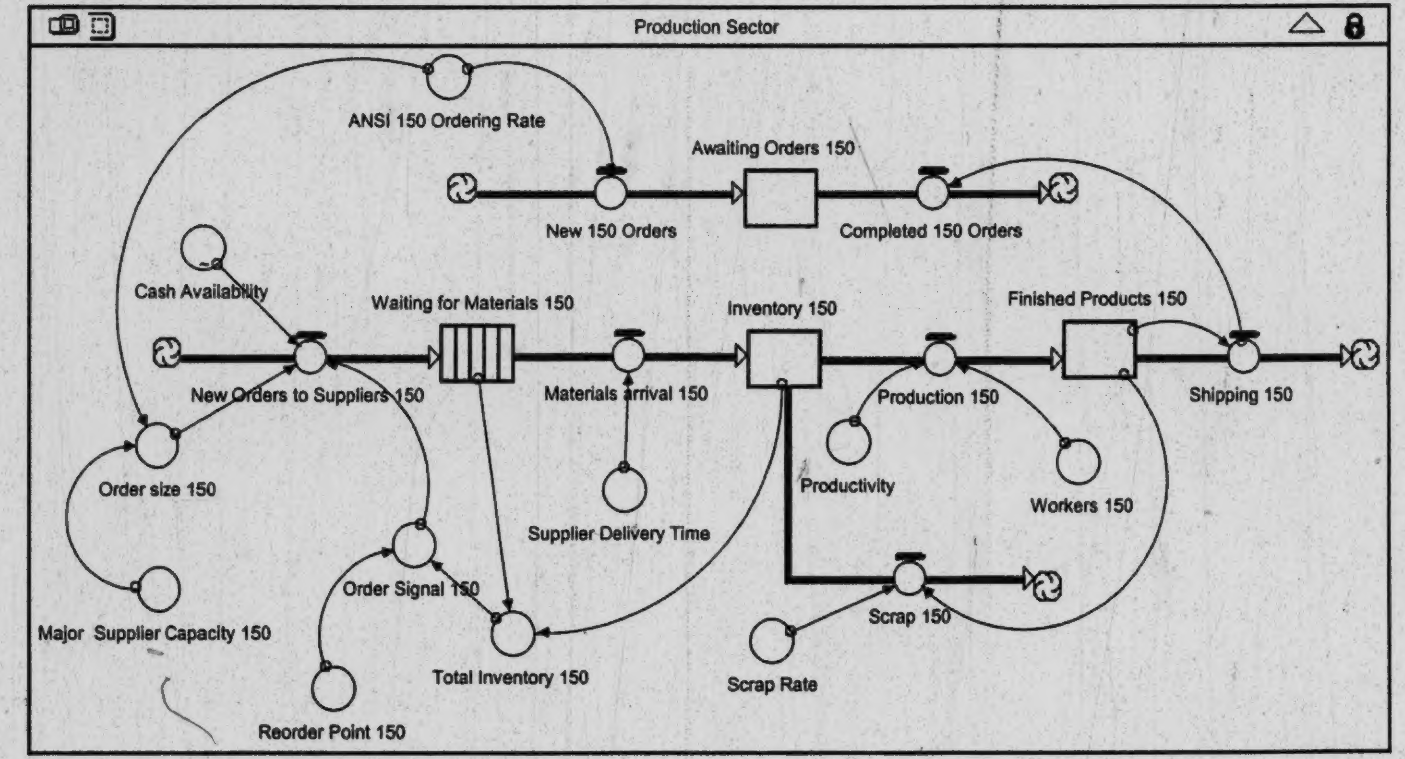
Appendix # 3

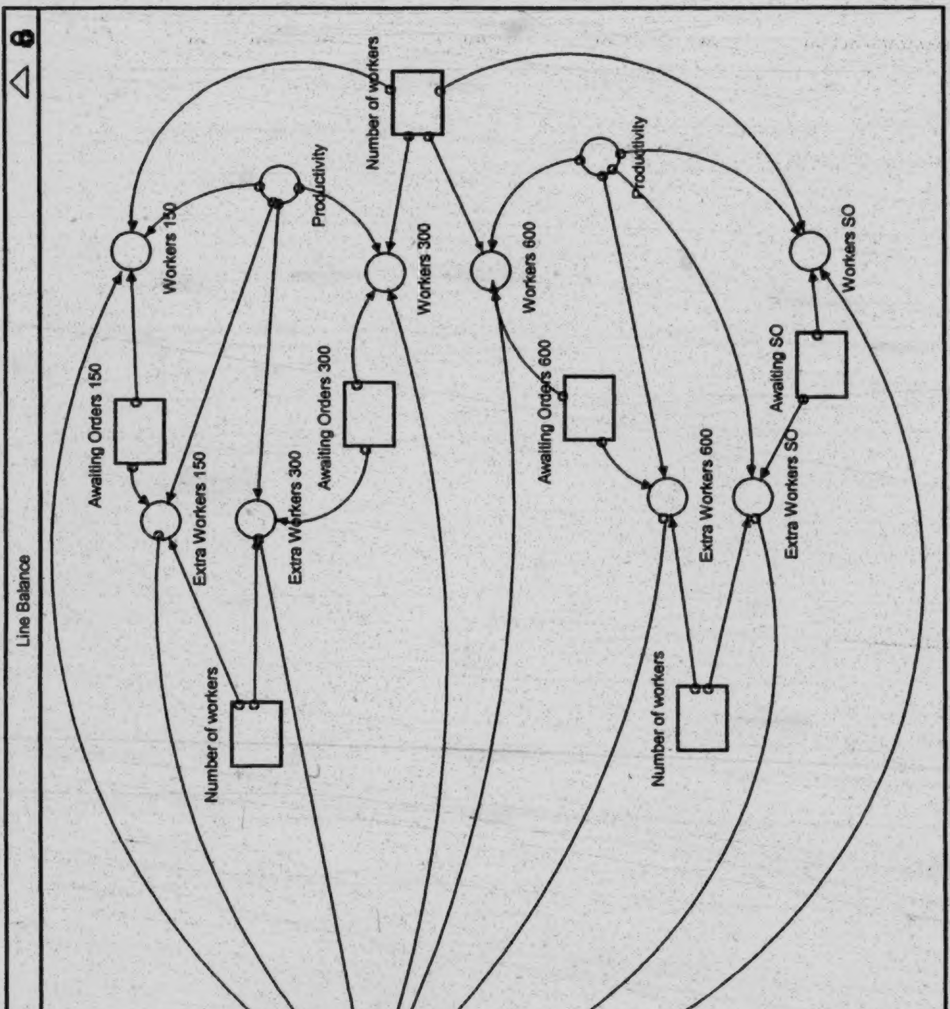
Simulation Model 1 – Without data

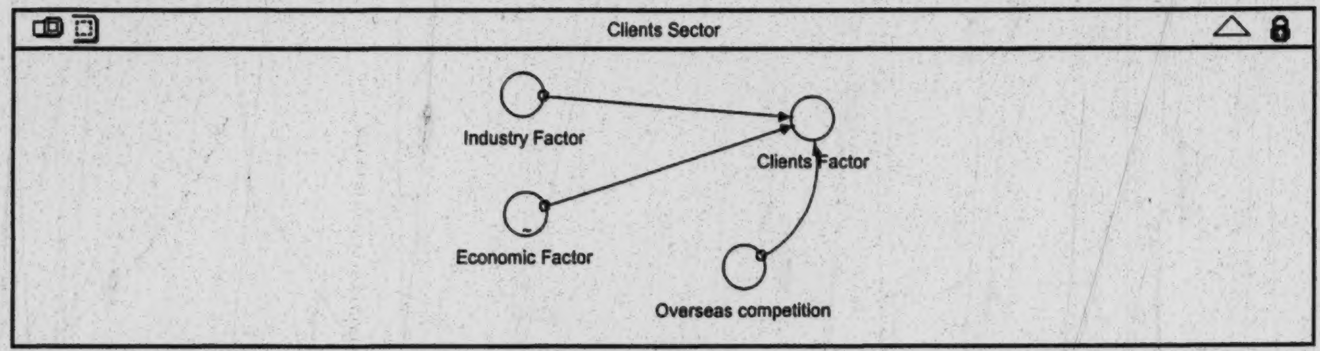

Finance Sector
Cash
Cash In
Cash Out
Cash Availability
Receivables
Revenue
Paid Receivables
Change In Days Receivables
Payables
Expenses
Payments
Change In Day Payables
Total Revenue
Net Income
Average salary per worker
Total Cost
Salaries
New 300 Orders
New 150 Revenue
New 300 Revenue
Price Change 300
Initial Price 150
Price 150
New 150 Orders
Price 300
SG&A
Initial Price 300
Price Change 150
Machining Cost
Price 600
New 600 Revenue
New SO Revenue
Price SO
Number of workers
Raw Material Cost
Initial Price 600
Initial Price SO
Price Change 600
New 600 Orders
New SO
Price Change SO

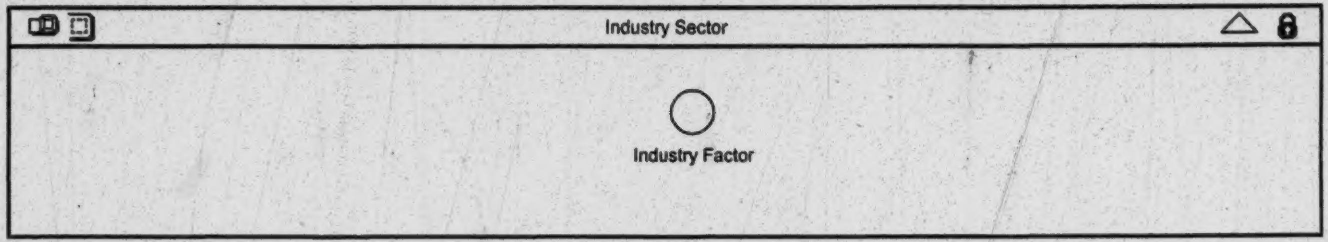

Distributors' Orders Sector
New SO
New 600 Orders
New 300 Orders
New 150 Orders
Last Month Orders
Orders of Month
Old Orders
Shipping 150
Shipping 300
Shipping 600
Shipping SO
Unmet Orders Calculation
Unmet Orders
Clients Factor
ANSI 150 Ordering Rate
Price Factor 150
Price Change 150
Clients Factor
ANSI 300 Ordering Rate
Price Factor 300
Price Change 300
ANSI 600 Ordering Rate
Price Factor 600
Price Change 600
Clients Factor
SO Rate
Price Factor SO
Price Change SO
Unmet Orders Factor

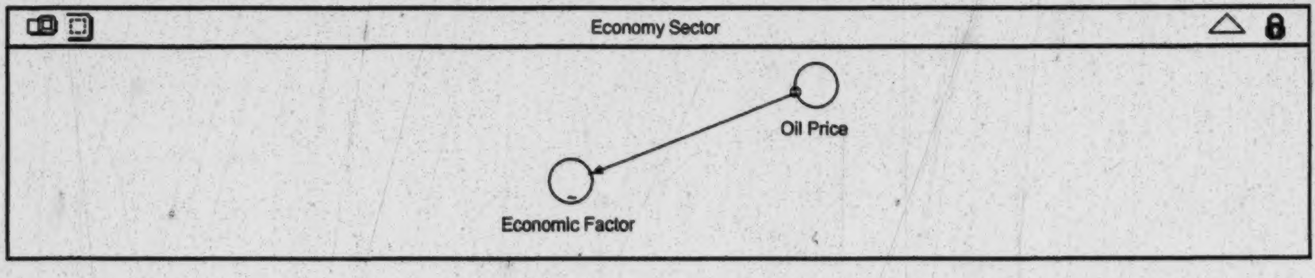

Suppliers Sector
Change in Raw Material Percentage
Raw Material Percentage
Raw Material Cost
Materials arrival SO
Materials arrival 600
Materials arrival 300
Materials arrival 150
Price 150
Price 300
Price 600
Price SO
Machining Cost
Machining percentage
Change in Machining Percentage


Production Sector
ANSI 150 Ordering Rate
Awaiting Orders 150
New 150 Orders
Completed 150 Orders
Cash Availability
Waiting for Materials 150
Inventory 150
Finished Products 150
New Orders to Suppliers 150
Materials arrival 150
Production 150
Shipping 150
Order size 150
Productivity
Workers 150
Supplier Delivery Time
Order Signal 150
Major Supplier Capacity 150
Total Inventory 150
Scrap 150
Scrap Rate
Reorder Point 150


Line Balance
Number of workers
Workers 150
Productivity
Workers 300
Workers 600
Productivity
Workers SO
Awaiting Orders 150
Awaiting Orders 300
Awaiting Orders 600
Awaiting SO
Extra Workers 150
Extra Workers 300
Extra Workers 600
Extra Workers SO
Number of workers
Number of workers
Available Extra Workers


Clients Sector
Industry Factor
Economic Factor
Clients Factor
Overseas competition


Industry Sector
Industry Factor


Economy Sector
Oil Price
Economic Factor

Appendix # 4

Table of Simulation Model Variables

Inputs		
Finance Sector	**Data**	**Explanation**
Cash availability		Current cash on hand
Revenue		Last Month Revenue
Receivables		Current Receivables
Payables		Current Payables
Days of Receivables		Days to get receivables from clients
Days of Payables		Days that takes to pay for suppliers orders
Price ANSI 150		Average Selling Price of Valve ANSI 150
Price ANSI 300		Average Selling Price of Valve ANSI 300
Price ANSI 600		Average Selling Price of Valve ANSI 600
Price SO		Average Selling Price of Special Orders
Average Salary per worker		Monthly Average Salary per Worker
Distributor Sector		
Number of workers		Total number of workers in the production floor
Last Month Orders		Total amount of orders gotten from clients including every type of valves
Line Balance Policy		Assumption that workers will be making all types of valves
Production Sector		
Awaiting Orders 150		Number of Orders that are waiting to be completed of valve ANSI 150
Awaiting Orders 300		Number of Orders that are waiting to be completed of valve ANSI 300
Awaiting Orders 600		Number of Orders that are waiting to be completed of valve ANSI 600
Awaiting SO		Number of Special Orders that are waiting to be completed
Order Size 150		Size of an order to a supplier of ANSI 150 valves
Order Size 300		Size of an order to a supplier of ANSI 300 valves
Order Size 600		Size of an order to a supplier of ANSI 600 valves
Order Size SO		Size of an order to a supplier of SO valves
Major Supplier Capacity 150		Maximum number of ANSI 150 valves that the major supplier can handle at a time

Major Supplier Capacity 300		Maximum number of ANSI 300 valves that the major supplier can handle at a time
Major Supplier Capacity 600		Maximum number of ANSI 600 valves that the major supplier can handle at a time
Inventory 150		Amount of complete sets of parts available to make ANSI 150 valves
Inventory 300		Amount of complete sets of parts available to make ANSI 300 valves
Inventory 600		Amount of complete sets of parts available to make ANSI 600 valves
Inventory SO		Amount of complete sets of parts available to make Special Orders
Reorder Point 150		Level of inventory in which a new order for materials must take place
Reorder Point 300		Level of inventory in which a new order for materials must take place
Reorder Point 600		Level of inventory in which a new order for materials must take place
Finished Products 150		Number of finished ANSI 150 valves in inventory
Finished Products 300		Number of finished ANSI 300 valves in inventory
Finished Products 600		Number of finished ANSI 600 valves in inventory
Finished Products SO		Number of finished Special Orders in inventory

Factors

Internal	Data	Explanation
% Raw Material Cost		Percentage from the total amount of revenue that corresponts to Raw Materials
% Machining Cost		Percentage from the total amount of revenue that corresponts to Machining Cost
Unmet Orders Factor		Which percentage of sales is lost for every unmet order
Cash Availability Factor		An order to a supplier only can be done if there is enough cash to pay for it
Scrap Rate		Percentage of finished products that are defective and must be scraped
Productivity		Number of valves made per worker each month
Overhead Cost		Administration Costs as a Percentage of the Overall Costs

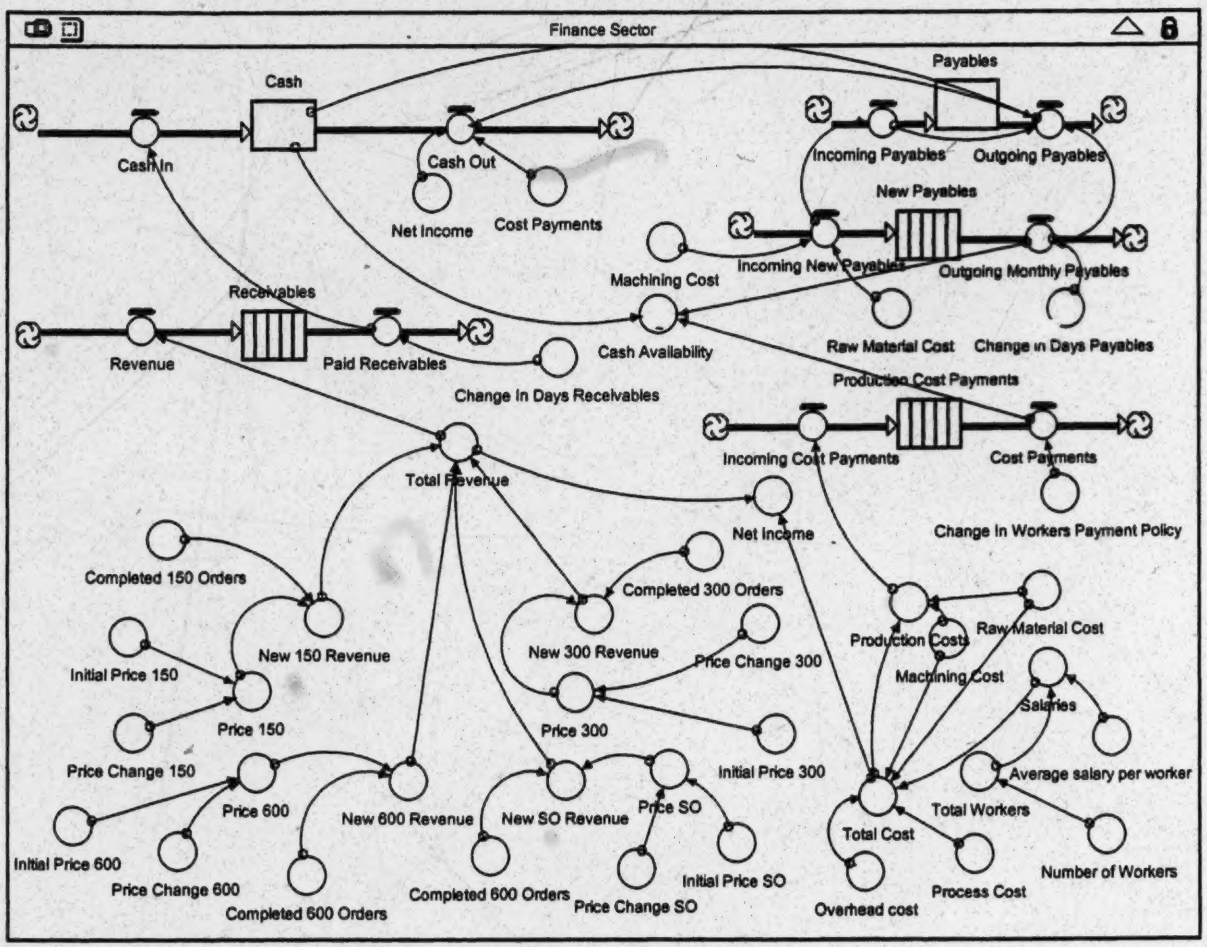
Outputs (Initial Data)

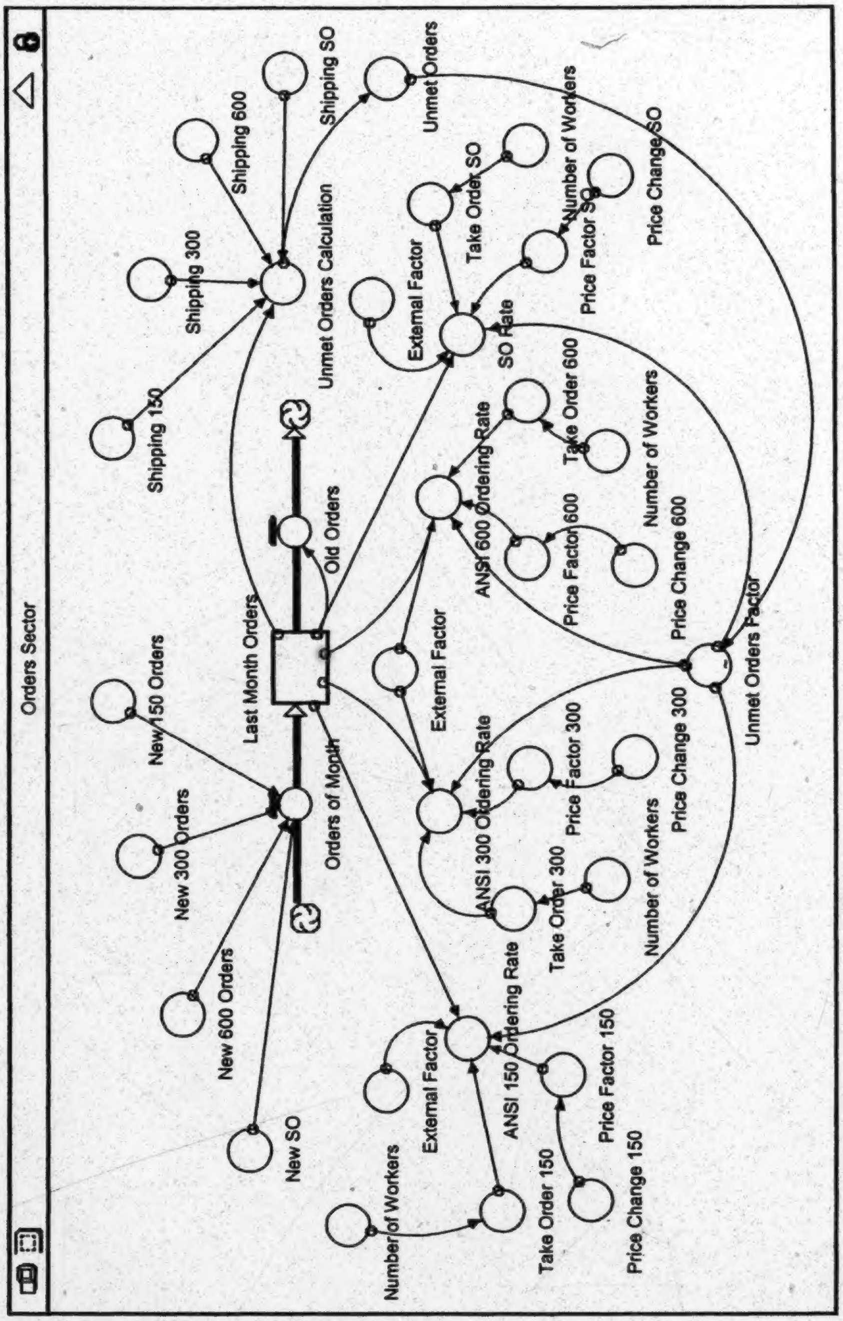
Finance Sector	Data	Explanation
Raw Material Cost		Last month Raw Material Cost
Machining Cost		Last month Machining Cost
Net Income		Last month Profit

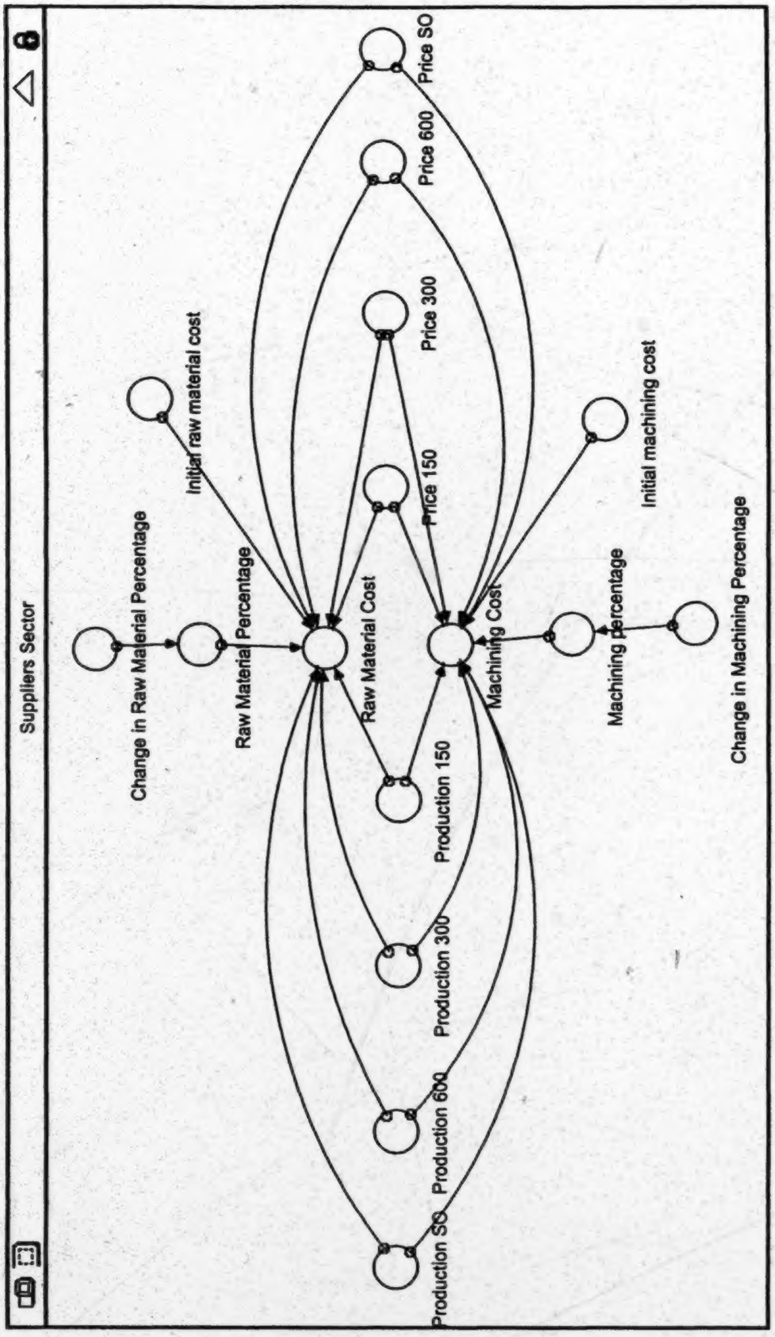
Distributor Sector		
ANSI 150 Ordering Rate		Last Month ANSI 150 Orders
ANSI 300 Ordering Rate		Last Month ANSI 300 Orders
ANSI 600 Ordering Rate		Last Month ANSI 600 Orders
Special Ordering Rate		Last Month Special Orders
Unmet Orders		Last Month Unmet Orders
Production Sector		
- Completed 150 Orders		Inventory of finished ANSI 150 valves
- Awaiting Orders 150		Pending ANSI 150 orders
- Scrap 150		Scraped units of ANSI 150 valves
- Inventory 150		Inventory of units of material for producing ANSI 150 Valves
- Completed 300 Orders		Inventory of finished ANSI 300 valves
- Awaiting Orders 300		Pending ANSI 300 orders
- Scrap 300		Scraped units of ANSI 300 valves
- Inventory 300		Inventory of units of material for producing ANSI 300 Valves
- Completed 600 orders		Inventory of finished ANSI 600 valves
- Awaiting Orders 600		Pending ANSI 600 orders
- Scrap 600		Scraped units of ANSI 600 valves
- Inventory 600		Inventory of units of material for producing ANSI 600 Valves
- Completed SO		Inventory of finished Special Orders
- Awaiting SO		Pending Special Orders
- Scrap SO		Scraped units of Special Orders
- Inventory SO		Inventory of units of material for producing Special Orders

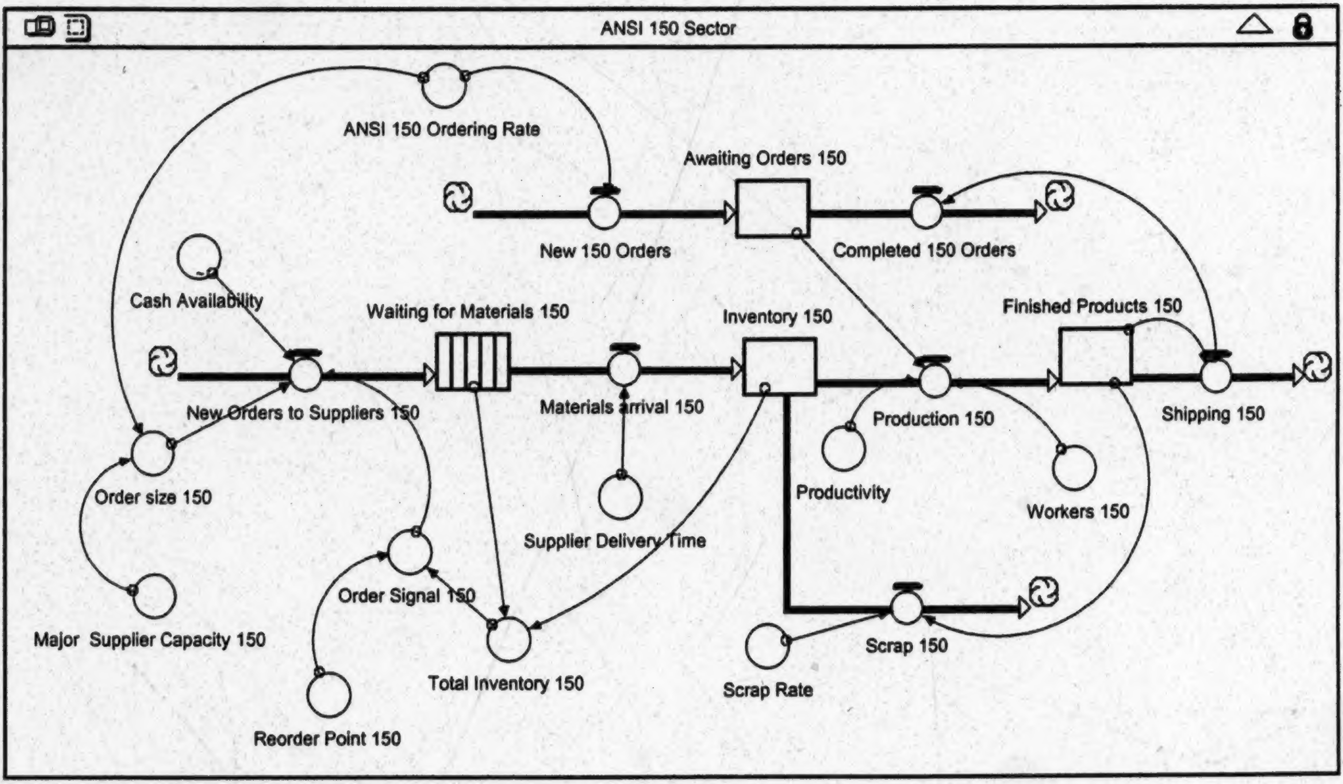
Appendix # 5

Simulation Model 2 – Filled with Data


Finance Sector
Cash
Cash In
Cash Out
Net Income
Cost Payments
Payables
Incoming Payables
Outgoing Payables
New Payables
Incoming New Payables
Outgoing Monthly Payables
Machining Cost
Raw Material Cost
Change in Days Payables
Receivables
Revenue
Paid Receivables
Cash Availability
Change In Days Receivables
Production Cost Payments
Incoming Cost Payments
Cost Payments
Change In Workers Payment Policy
Total Revenue
Net Income
Completed 150 Orders
New 150 Revenue
Initial Price 150
Price 150
Price Change 150
Price 600
New 600 Revenue
Initial Price 600
Price Change 600
Completed 600 Orders
Completed 300 Orders
New 300 Revenue
Price Change 300
Price 300
Initial Price 300
New SO Revenue
Price SO
Completed 600 Orders
Price Change SO
Initial Price SO
Production Costs
Raw Material Cost
Machining Cost
Salaries
Average salary per worker
Total Workers
Total Cost
Process Cost
Number of Workers
Overhead cost

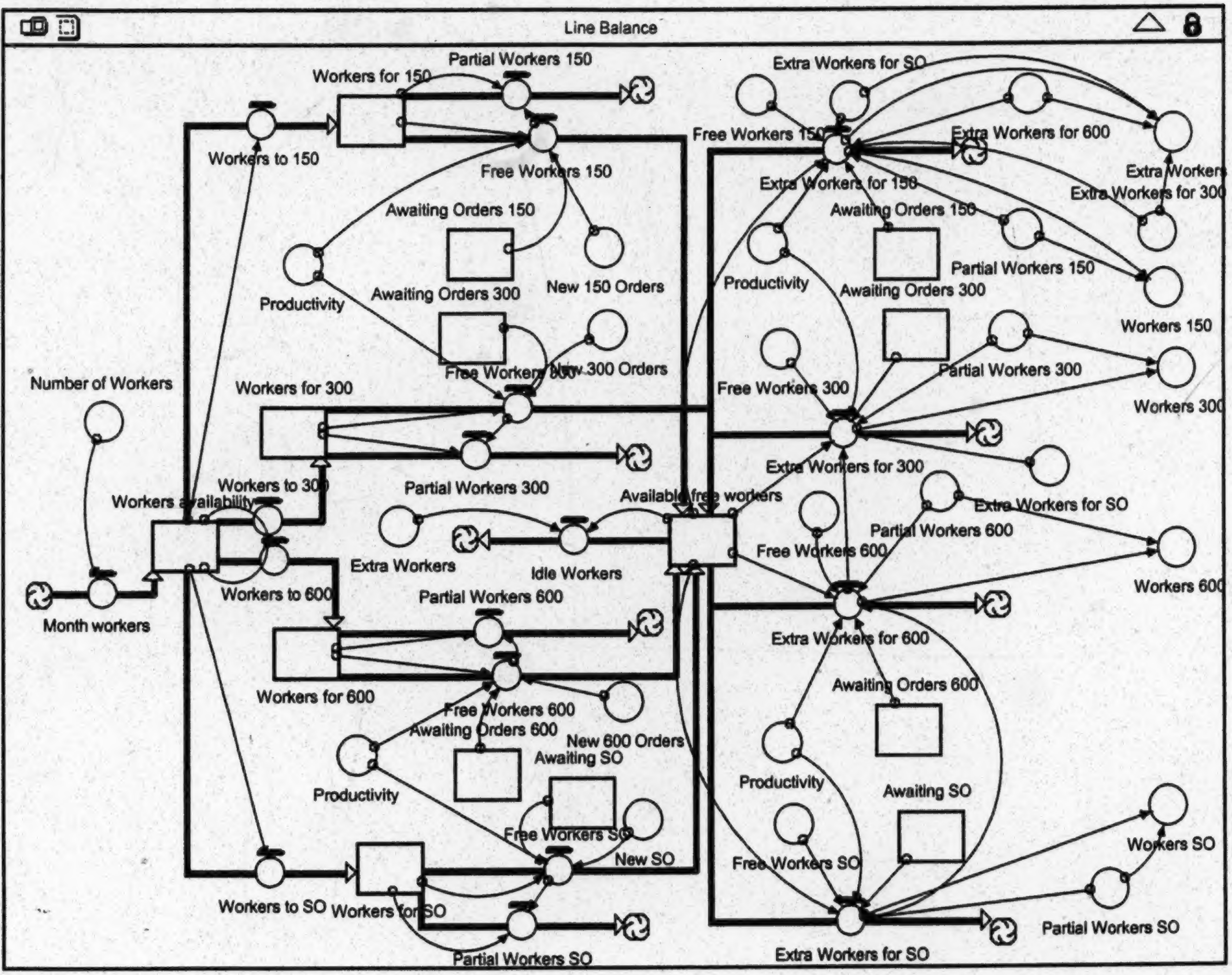

Orders Sector
Orders of Month
Last Month Orders
Old Orders
New 150 Orders
New 300 Orders
New 600 Orders
New SO
Shipping 150
Shipping 300
Shipping 600
Shipping SO
Unmet Orders Calculation
Unmet Orders
Unmet Orders Factor
External Factor
SO Rate
Take Order SO
Number of Workers
Price Factor SO
Price Change SO
ANSI 600 Ordering Rate
Take Order 600
Number of Workers
Price Factor 600
Price Change 600
External Factor
ANSI 300 Ordering Rate
Price Factor 300
Price Change 300
Take Order 300
Number of Workers
ANSI 150 Ordering Rate
External Factor
Price Factor 150
Price Change 150
Take Order 150
Number of Workers

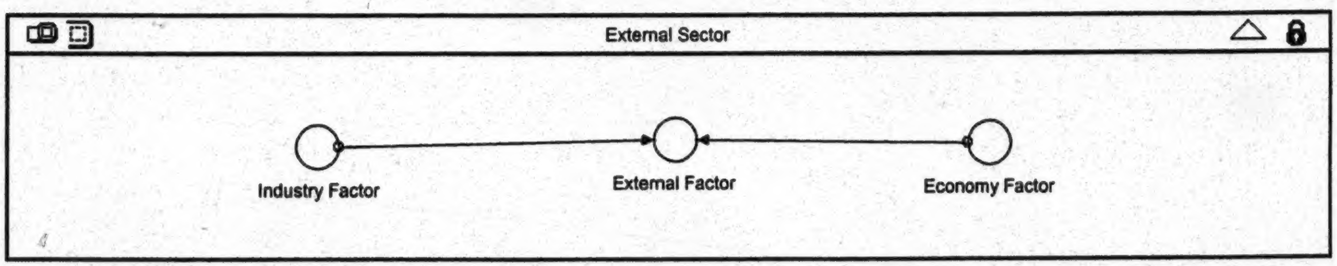

Suppliers Sector
Change in Raw Material Percentage
Raw Material Percentage
Initial raw material cost
Raw Material Cost
Machining Cost
Price 150
Price 300
Price 600
Price SO
Production 150
Production 300
Production 600
Production SO
Machining percentage
Initial machining cost
Change in Machining Percentage

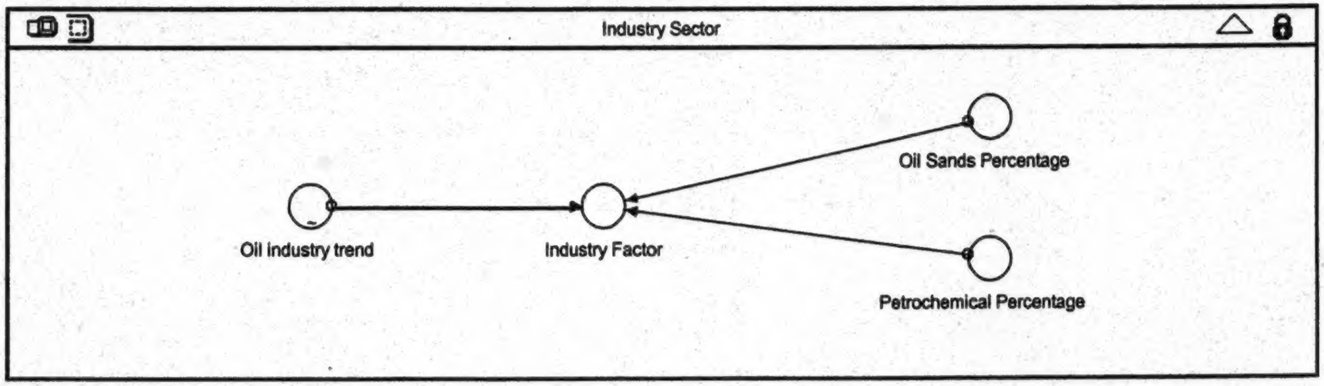

ANSI 150 Sector
ANSI 150 Ordering Rate
Awaiting Orders 150
New 150 Orders
Completed 150 Orders
Cash Availability
Waiting for Materials 150
Inventory 150
Finished Products 150
New Orders to Suppliers 150
Materials arrival 150
Production 150
Shipping 150
Order size 150
Productivity
Workers 150
Supplier Delivery Time
Order Signal 150
Major Supplier Capacity 150
Total Inventory 150
Scrap 150
Scrap Rate
Reorder Point 150

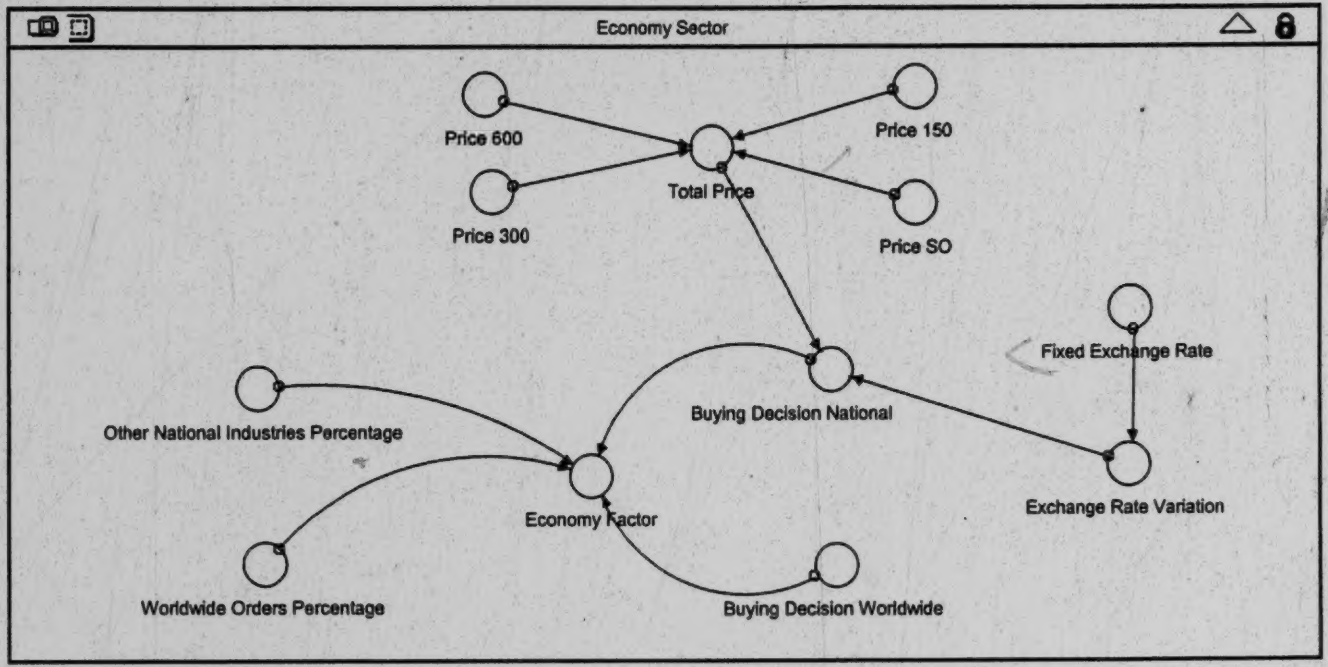
Note: The section for ANSI 150 represents the production sector specifically for ANSI 150 valves.

Each type of valve has its own section.


Line Balance
Workers for 150
Partial Workers 150
Workers to 150
Free Workers 150
Awaiting Orders 150
Productivity
Awaiting Orders 300
New 150 Orders
Number of Workers
Workers for 300
Free Workers 300
New 300 Orders
Workers to 300
Partial Workers 300
Workers availability
Extra Workers
Idle Workers
Available free workers
Month workers
Workers to 600
Partial Workers 600
Workers for 600
Free Workers 600
Awaiting Orders 600
New 600 Orders
Awaiting SO
Productivity
Free Workers SO
New SO
Workers to SO
Workers for SO
Partial Workers SO
Extra Workers for SO
Free Workers 150
Extra Workers for 600
Extra Workers
Extra Workers for 150
Extra Workers for 300
Awaiting Orders 150
Productivity
Partial Workers 150
Awaiting Orders 300
Workers 150
Free Workers 300
Partial Workers 300
Workers 300
Extra Workers for 300
Extra Workers for SO
Partial Workers 600
Free Workers 600
Workers 600
Extra Workers for 600
Awaiting Orders 600
Productivity
Awaiting SO
Free Workers SO
Workers SO
Partial Workers SO
Extra Workers for SO


External Sector
Industry Factor
External Factor
Economy Factor


Industry Sector
Oil Sands Percentage
Oil industry trend
Industry Factor
Petrochemical Percentage


Economy Sector
Price 600
Price 150
Total Price
Price 300
Price SO
Fixed Exchange Rate
Buying Decision National
Other National Industries Percentage
Exchange Rate Variation
Economy Factor
Worldwide Orders Percentage
Buying Decision Worldwide

Appendix # 6

ANSI 150 Production Sub-Sector

```
□ Awaiting_Orders_150(t) = Awaiting_Orders_150(t - dt) + (New_150_Orders - Completed_150_Orders) * dt
  INIT Awaiting_Orders_150 = 45
  INFLOWS:
    ⇨ New_150_Orders = IF(ANSI_150_Ordering_Rate>0)THEN(ANSI_150_Ordering_Rate)ELSE(0)
  OUTFLOWS:
    ⇨ Completed_150_Orders = Shipping_150
□ Finished_Products_150(t) = Finished_Products_150(t - dt) + (Production_150 - Shipping_150) * dt
  INIT Finished_Products_150 = 45
  INFLOWS:
    ⇨ Production_150 =
        IF(TIME<=1)THEN(Awaiting_Orders_150)ELSE(IF(Awaiting_Orders_150>0)AND(Workers_150>0)TH
        EN(Workers_150*Productivity)ELSE(0))
  OUTFLOWS:
    ⇨ Shipping_150 = Finished_Products_150
□ Inventory_150(t) = Inventory_150(t - dt) + (Materials_arrival_150 + Extra_Inventory_150 - Production_150 -
  Scrap_150) * dt
  INIT Inventory_150 = 750
  INFLOWS:
    ⇨ Materials_arrival_150 = CONVEYOR OUTFLOW
         TRANSIT TIME = Supplier_Delivery_Time
    ⇨ Extra_Inventory_150 = IF(TIME=1)THEN(Extra_Inventory_Order_150)ELSE(0)
  OUTFLOWS:
    ⇨ Production_150 =
        IF(TIME<=1)THEN(Awaiting_Orders_150)ELSE(IF(Awaiting_Orders_150>0)AND(Workers_150>0)TH
        EN(Workers_150*Productivity)ELSE(0))
    ⇨ Scrap_150 = Finished_Products_150*Scrap_Rate
▥ Waiting_for_Materials_150(t) = Waiting_for_Materials_150(t - dt) + (New_Orders_to_Suppliers_150 -
  Materials_arrival_150) * dt
  INIT Waiting_for_Materials_150 = 0
   TRANSIT TIME = varies
   INFLOW LIMIT = INF
   CAPACITY = INF
  INFLOWS:
    ⇨ New_Orders_to_Suppliers_150 =
        PULSE(Order_Signal_150*Order_size_150*Cash_Availability_Factor,1,1)
  OUTFLOWS:
    ⇨ Materials_arrival_150 = CONVEYOR OUTFLOW
         TRANSIT TIME = Supplier_Delivery_Time
○ Cash_For_Inventory_150 = Extra_Inventory_150*Price_150
○ Extra_Inventory_Order_150 = 0
○ Major__Supplier_Capacity_150 = 60
○ Order_Signal_150 = IF(Total_Inventory_150<=Reorder_Point_150) THEN (1) ELSE (0)
○ Order_size_150 =
  IF(Major__Supplier_Capacity_150>=ANSI_150_Ordering_Rate)THEN(ANSI_150_Ordering_Rate*2)ELSE(A
  NSI_150_Ordering_Rate+Major__Supplier_Capacity_150)
```

○ Percentage_150 = Awaiting_Orders_150/Awaiting_Orders
○ Reorder_Point_150 = 280
○ Scrap_Rate = 0.01
○ Supplier_Delivery_Time = 1
○ Total_Inventory_150 = Waiting_for_Materials_150+Inventory_150
○ Workers_150 = Number_of_Workers*Percentage_150

ANSI 300 Production Sub-Sector

☐ Awaiting_Orders_300(t) = Awaiting_Orders_300(t - dt) + (New_300_Orders - Completed_300_Orders) * dt
INIT Awaiting_Orders_300 = 25
INFLOWS:
⇨ New_300_Orders = IF(ANSI_300_Ordering_Rate>0)THEN(ANSI_300_Ordering_Rate)ELSE(0)
OUTFLOWS:
⇨ Completed_300_Orders = Shipping_300

☐ Finished_Products_300(t) = Finished_Products_300(t - dt) + (Production_300 - Shipping_300) * dt
INIT Finished_Products_300 = 25
INFLOWS:
⇨ Production_300 = IF(TIME<=1)THEN(Awaiting_Orders_300)ELSE(IF(Awaiting_Orders_300>0)AND(Workers_300>0)THEN(Workers_300*Productivity)ELSE(0))
OUTFLOWS:
⇨ Shipping_300 = Finished_Products_300

☐ Inventory_300(t) = Inventory_300(t - dt) + (Materials_arrival_300 + Extra_Inventory_300 - Production_300 - Scrap_300) * dt
INIT Inventory_300 = 550
INFLOWS:
⇨ Materials_arrival_300 = CONVEYOR OUTFLOW
TRANSIT TIME = Supplier_Delivery_Time
⇨ Extra_Inventory_300 = IF(TIME=1)THEN(Extra_Inventory_Order_300)ELSE(0)
OUTFLOWS:
⇨ Production_300 = IF(TIME<=1)THEN(Awaiting_Orders_300)ELSE(IF(Awaiting_Orders_300>0)AND(Workers_300>0)THEN(Workers_300*Productivity)ELSE(0))
⇨ Scrap_300 = Finished_Products_300*Scrap_Rate

▥ Waiting_for_Materials_300(t) = Waiting_for_Materials_300(t - dt) + (New_Orders_to_Suppliers_300 - Materials_arrival_300) * dt
INIT Waiting_for_Materials_300 = 0
TRANSIT TIME = varies
INFLOW LIMIT = INF
CAPACITY = INF
INFLOWS:
⇨ New_Orders_to_Suppliers_300 = PULSE(Order_Signal_300*Order_size_300*Cash_Availability_Factor,1,1)
OUTFLOWS:
⇨ Materials_arrival_300 = CONVEYOR OUTFLOW
TRANSIT TIME = Supplier_Delivery_Time

○ Cash_For_Inventory_300 = Extra_Inventory_300*Price_300

```
○ Extra_Inventory_Order_300 = 0
○ Major__Supplier_Capacity_300 = 40
○ Order_Signal_300 = IF(Total_Inventory_300<=Reorder_Point_300) THEN (1) ELSE (0)
○ Order_size_300 =
  IF(Major__Supplier_Capacity_300>=ANSI_300_Ordering_Rate)THEN(ANSI_300_Ordering_Rate*2)ELSE(A
  NSI_300_Ordering_Rate+Major__Supplier_Capacity_300)
○ Percentage_300 = Awaiting_Orders_300/Awaiting_Orders
○ Reorder_Point_300 = 228
○ Total_Inventory_300 = Waiting_for_Materials_300+Inventory_300
○ Workers_300 = Number_of_Workers*Percentage_300
```

ANSI 600 Production Sub-Sector

```
□ Awaiting_Orders_600(t) = Awaiting_Orders_600(t - dt) + (New_600_Orders - Completed_600_Orders) * dt
  INIT Awaiting_Orders_600 = 3
   INFLOWS:
     ⇨ New_600_Orders = IF(ANSI_600_Ordering_Rate>0)THEN(ANSI_600_Ordering_Rate)ELSE(0)
   OUTFLOWS:
     ⇨ Completed_600_Orders = Shipping_600
□ Finished_Products_600(t) = Finished_Products_600(t - dt) + (Production_600 - Shipping_600) * dt
  INIT Finished_Products_600 = 3
   INFLOWS:
     ⇨ Production_600 =
       IF(TIME<=1)THEN(Awaiting_Orders_600)ELSE(IF(Awaiting_Orders_600>0)AND(Workers_600>0)TH
       EN(Workers_600*Productivity)ELSE(0))
   OUTFLOWS:
     ⇨ Shipping_600 = Finished_Products_600
□ Inventory_600(t) = Inventory_600(t - dt) + (Materials_arrival_600 + Extra_Inventory_600 - Production_600 -
  Scrap_600) * dt
  INIT Inventory_600 = 50
   INFLOWS:
     ⇨ Materials_arrival_600 = CONVEYOR OUTFLOW
        TRANSIT TIME = Supplier_Delivery_Time
     ⇨ Extra_Inventory_600 = IF(TIME=1)THEN(Extra_Inventory_Order_600)ELSE(0)
   OUTFLOWS:
     ⇨ Production_600 =
       IF(TIME<=1)THEN(Awaiting_Orders_600)ELSE(IF(Awaiting_Orders_600>0)AND(Workers_600>0)TH
       EN(Workers_600*Productivity)ELSE(0))
     ⇨ Scrap_600 = Finished_Products_600*Scrap_Rate
▥ Waiting_for_Materials_600(t) = Waiting_for_Materials_600(t - dt) + (New_Orders_to_Suppliers_600 -
  Materials_arrival_600) * dt
  INIT Waiting_for_Materials_600 = 0
   TRANSIT TIME = varies
   INFLOW LIMIT = INF
   CAPACITY = INF
   INFLOWS:
     ⇨ New_Orders_to_Suppliers_600 =
       PULSE(Order_Signal_600*Order_size_600*Cash_Availability_Factor,1,1)
```

OUTFLOWS:

⇨ Materials_arrival_600 = CONVEYOR OUTFLOW
TRANSIT TIME = Supplier_Delivery_Time

○ Cash_For_Inventory_600 = Extra_Inventory_600*Price_600
○ Extra_Inventory_Order_600 = 0
○ Major__Supplier_Capacity_600 = 10
○ Order_Signal_600 = IF(Total_Inventory_600<=Reorder_Point_600) THEN (1) ELSE (0)
○ Order_size_600 = IF(Major__Supplier_Capacity_600>=ANSI_600_Ordering_Rate)THEN(ANSI_600_Ordering_Rate*2)ELSE(ANSI_600_Ordering_Rate+Major__Supplier_Capacity_600)
○ Percentage_600 = Awaiting_Orders_600/Awaiting_Orders
○ Reorder_Point_600 = 100
○ Total_Inventory_600 = Waiting_for_Materials_600+Inventory_600
○ Workers_600 = Number_of_Workers*Percentage_600

Economy Sub-Sector

○ After_Forecast_Exchange_Rate = 1.10
○ Buying_Decision_National = ((1+(Exchange_Rate_Variation*9.77))*0.55)+(0.45)
○ Buying_Decision_Worldwide = 1.1
○ Economy_Factor = ((Buying_Decision_National*Other_National_Industries_Percentage)+(Buying_Decision_Worldwide*Worldwide_Orders_Percentage))
○ Exchange_Rate_Variation = IF(TIME>17) THEN((After_Forecast_Exchange_Rate*NORMAL(1, 0.05,100))-After_Forecast_Exchange_Rate)ELSE((Exchange_Rate_Forecast*NORMAL(1, 0.05,100))-Exchange_Rate_Forecast)
○ Other_National_Industries_Percentage = .09
○ Worldwide_Orders_Percentage = .35
⊘ Exchange_Rate_Forecast = GRAPH(Initial_Time+TIME)
(0.00, 1.24), (1.00, 1.22), (2.00, 1.21), (3.00, 1.18), (4.00, 1.18), (5.00, 1.18), (6.00, 1.16), (7.00, 1.17), (8.00, 1.14), (9.00, 1.11), (10.0, 1.12), (11.0, 1.12), (12.0, 1.10), (13.0, 1.11), (14.0, 1.12), (15.0, 1.10), (16.0, 1.12), (17.0, 1.11), (18.0, 1.11), (19.0, 1.12), (20.0, 1.12), (21.0, 1.12), (22.0, 1.12), (23.0, 1.12), (24.0, 1.12), (25.0, 1.12), (26.0, 1.12), (27.0, 1.12), (28.0, 1.12), (29.0, 1.12), (30.0, 1.12), (31.0, 1.11), (32.0, 1.11), (33.0, 1.11), (34.0, 1.11), (35.0, 1.11), (36.0, 1.11), (37.0, 1.11), (38.0, 1.11), (39.0, 1.11), (40.0, 1.11), (41.0, 1.11), (42.0, 1.11), (43.0, 1.11), (44.0, 1.11), (45.0, 1.11), (46.0, 1.11), (47.0, 1.11), (48.0, 1.11), (49.0, 1.11), (50.0, 1.11), (51.0, 1.11), (52.0, 1.11)...

External Sector

○ External_Factor = (Economy_Factor+Industry_Factor)*Sales_Factor
○ Sales_Factor = NORMAL(1,0.40,300)

Financial Sector

☐ Cash(t) = Cash(t - dt) + (Cash_In - Cash_Out) * dt
INIT Cash = 1350000

INFLOWS:

⇨ Cash_In = Paid_Receivables

OUTFLOWS:

```
    ⇨ Cash_Out =
        IF(time<=0)THEN(1500000)ELSE(IF(Net_Income>0)THEN(Cost_Payments+Payables_Out+Net_Inco
        me+Cash_For_Inventory)ELSE(Cost_Payments+Payables_Out+Cash_For_Inventory))
▥ New_Payables(t) = New_Payables(t - dt) + (Incoming_New_Payables - Outgoing_Monthly_Payables) * dt
  INIT New_Payables = 0
   TRANSIT TIME = varies
   INFLOW LIMIT = INF
   CAPACITY = INF
  INFLOWS:
    ⇨ Incoming_New_Payables = Raw_Material_Cost+Machining_Cost
  OUTFLOWS:
    ⇨ Outgoing_Monthly_Payables = CONVEYOR OUTFLOW
         TRANSIT TIME = Payables_time_policy+NORMAL(Change_in_Days_Payables,0.5,60)
☐ Payables(t) = Payables(t - dt) + (Incoming_Payables - Payables_Out) * dt
  INIT Payables = 849084
  INFLOWS:
    ⇨ Incoming_Payables = Incoming_New_Payables
  OUTFLOWS:
    ⇨ Payables_Out =
        IF(Incoming_Payables>0)AND(Outgoing_Monthly_Payables<Cash)THEN(Outgoing_Monthly_Payabl
        es)ELSE(IF(Cash>440000)THEN(440000)ELSE(0))
▥ Production_Cost_Payments(t) = Production_Cost_Payments(t - dt) + (Incoming_Cost_Payments -
  Cost_Payments) * dt
  INIT Production_Cost_Payments = 0
   TRANSIT TIME = varies
   INFLOW LIMIT = INF
   CAPACITY = INF
  INFLOWS:
    ⇨ Incoming_Cost_Payments = Production_Costs
  OUTFLOWS:
    ⇨ Cost_Payments = CONVEYOR OUTFLOW
         TRANSIT TIME = 1+Change_In_Workers_Payment_Policy
▥ Receivables(t) = Receivables(t - dt) + (Revenue - Paid_Receivables) * dt
  INIT Receivables = 1629335
   TRANSIT TIME = varies
   INFLOW LIMIT = INF
   CAPACITY = INF
  INFLOWS:
    ⇨ Revenue = Total_Sales
  OUTFLOWS:
    ⇨ Paid_Receivables = CONVEYOR OUTFLOW
         TRANSIT TIME =
        1.75+NORMAL(((Time_Receivables_Min-Time_Receivables_Max)/2),((Time_Receivables_Max-Time
        _Receivables_Min)/2),60)
○ Average_salary_per_worker = 3300
○ Change_in_Days_Payables = -0.5
○ Change_In_Workers_Payment_Policy = 0
```

○ Initial_Price_150 = 5900
○ Initial_Price_300 = 8850
○ Initial_Price_600 = 16500
○ Initial_Price_SO = 12000
○ Initial_Revenue = 1100000
○ Net_Income = Total_Sales-Total_Cost
○ New_150_Sale = Price_150*Shipping_150
○ New_300_Sale = Shipping_300*Price_300
○ New_600_Sale = Shipping_600*Price_600
○ New_Price_150 = 0
○ New_Price_300 = 0
○ New_Price_600 = 0
○ New_Price_SO = 0
○ New_SO_Sale = Shipping_SO*Price_SO
○ Number_of_Workers = 6
○ Overhead_cost = 0.055
○ Payables_time_policy = 1
○ Price_150 = IF(New_Price_150)=0THEN(Initial_Price_150)ELSE(New_Price_150)
○ Price_300 = IF(New_Price_300)=0THEN(Initial_Price_300)ELSE(New_Price_300)
○ Price_600 = IF(New_Price_600)=0THEN(Initial_Price_600)ELSE(New_Price_600)
○ Price_Change_150 = IF(New_Price_150=0)THEN(0)ELSE((New_Price_150/Initial_Price_150)-1)
○ Price_Change_300 = IF(New_Price_300=0)THEN(0)ELSE((New_Price_300/Initial_Price_300)-1)
○ Price_Change_600 = IF(New_Price_600=0)THEN(0)ELSE((New_Price_600/Initial_Price_600)-1)
○ Price_Change_SO = IF(New_Price_SO=0)THEN(0)ELSE((New_Price_SO/Initial_Price_SO)-1)
○ Price_SO = IF(New_Price_SO)=0THEN(Initial_Price_SO)ELSE(New_Price_SO)
○ Process_Cost = 0.05
○ Production_Costs = Total_Cost-Raw_Material_Cost-Machining_Cost
○ Salaries = Total_Workers*Average_salary_per_worker
○ Staff = 9
○ Time_Receivables_Max = 2
○ Time_Receivables_Min = 1.5
○ Total_Cost = (Machining_Cost+Raw_Material_Cost+Salaries)*(1+Process_Cost+Overhead_cost)
○ Total_Sales =
IF(TIME<=0)THEN(Initial_Revenue)ELSE(New_150_Sale+New_300_Sale+New_600_Sale+New_SO_Sale)

○ Total_Workers = Staff+Number_of_Workers
⊘ Cash_Availability_Factor = GRAPH(Cash/(Cost_Payments+Outgoing_Monthly_Payables))
(0.00, 0.00), (0.25, 0.00), (0.5, 0.00), (0.75, 0.00), (1.00, 1.00)

Industry Sub-Sector

○ Industry_Factor = (Oil_industry_trend*(Oil_Sands_Percentage+Petrochemical_Percentage))
○ Initial_Time = 1
○ Oil_Sands_Percentage = .340
○ Petrochemical_Percentage = .220

⊘ Oil_industry_trend = GRAPH(Initial_Time+TIME)
(0.00, 1.02), (1.00, 1.02), (2.00, 1.02), (3.00, 1.02), (4.00, 1.02), (5.00, 1.02), (6.00, 1.02), (7.00, 1.01), (8.00, 1.01), (9.00, 1.01), (10.0, 1.01), (11.0, 1.01), (12.0, 1.01), (13.0, 1.01), (14.0, 1.01), (15.0, 1.01), (16.0, 1.01), (17.0, 1.01), (18.0, 1.01), (19.0, 1.02), (20.0, 1.02), (21.0, 1.02), (22.0, 1.02), (23.0, 1.02), (24.0, 1.02), (25.0, 1.02), (26.0, 1.02), (27.0, 1.02), (28.0, 1.02), (29.0, 1.02), (30.0, 1.02), (31.0, 1.02), (32.0, 1.02), (33.0, 1.02), (34.0, 1.02), (35.0, 1.02), (36.0, 1.02), (37.0, 1.02), (38.0, 1.02), (39.0, 1.02), (40.0, 1.02), (41.0, 1.02), (42.0, 1.02), (43.0, 1.01), (44.0, 1.01), (45.0, 1.01), (46.0, 1.01), (47.0, 1.01), (48.0, 1.01), (49.0, 1.01), (50.0, 1.01), (51.0, 1.01), (52.0, 1.01)...

Materials Cost Sub-Sector

○ Initial_machining_cost = 255000
○ Initial_raw_material_cost = 146000
○ Machining_Cost =
IF(TIME<=0)THEN(Initial_machining_cost)ELSE(Machining_percentage*((Shipping_150*Price_150)+(Shipping_300*Price_300)+(Shipping_600*Price_600)+(Shipping_SO*Price_SO))*(1+Scrap_Rate))
○ Machining_percentage = 0.35
○ Raw_Material_Cost =
IF(TIME<=0)THEN(Initial_raw_material_cost)ELSE(Raw_Material_Percentage*((Shipping_150*Price_150)+(Shipping_300*Price_300)+(Shipping_600*Price_600)+(Shipping_SO*Price_SO))*(1+Scrap_Rate))
○ Raw_Material_Percentage = 0.2

Orders Sector

☐ Last_Month_Orders_150(t) = Last_Month_Orders_150(t - dt) + (Orders_of_Month_150 - Old_Orders_150) * dt
INIT Last_Month_Orders_150 = 45
INFLOWS:
⇨ Orders_of_Month_150 = New_150_Orders
OUTFLOWS:
⇨ Old_Orders_150 = Last_Month_Orders_150
☐ Last_Month_Orders_300(t) = Last_Month_Orders_300(t - dt) + (Orders_of_Month_300 - Old_Orders_300) * dt
INIT Last_Month_Orders_300 = 25
INFLOWS:
⇨ Orders_of_Month_300 = New_300_Orders
OUTFLOWS:
⇨ Old_Orders_300 = Last_Month_Orders_300
☐ Last_Month_Orders_600(t) = Last_Month_Orders_600(t - dt) + (Orders_of_Month_600 - Old_Orders_600) * dt
INIT Last_Month_Orders_600 = 3
INFLOWS:
⇨ Orders_of_Month_600 = New_600_Orders
OUTFLOWS:
⇨ Old_Orders_600 = Last_Month_Orders_600
☐ Last_Month_Orders_SO(t) = Last_Month_Orders_SO(t - dt) + (Orders_of_Month_SO - Old_Orders_SO) * dt
INIT Last_Month_Orders_SO = 10
INFLOWS:
⇨ Orders_of_Month_SO = New_SO

```
OUTFLOWS:
  ⇨ Old_Orders_SO = Last_Month_Orders_SO
○ ANSI_150_Ordering_Rate =
  IF((Take_Order_150*(Last_Month_Orders_150*External_Factor*Unmet_Orders_Factor_150)*(1-Price_Facto
  r_150))>0)THEN(Take_Order_150*(Last_Month_Orders_150*External_Factor*Unmet_Orders_Factor_150)*(
  1-Price_Factor_150))ELSE(0)
○ ANSI_300_Ordering_Rate =
  IF((Last_Month_Orders_300*External_Factor*Unmet_Orders_Factor_300*(1-Price_Factor_300)*Take_Order
  _300)>0)THEN(Last_Month_Orders_300*External_Factor*Unmet_Orders_Factor_300*(1-Price_Factor_300)*
  Take_Order_300)ELSE(0)
○ ANSI_600_Ordering_Rate =
  IF(((Last_Month_Orders_600*External_Factor*Unmet_Orders_Factor_600*(1-Price_Factor_600))*Take_Ord
  er_600)>0)THEN((Last_Month_Orders_600*External_Factor*Unmet_Orders_Factor_600*(1-Price_Factor_60
  0))*Take_Order_600)ELSE(0)
○ Initial_Unmet_Orders_150 = 0
○ Initial_Unmet_Orders_300 = 0
○ Initial_Unmet_Orders_600 = 0
○ Initial_Unmet_Orders_SO = 0
○ Price_Factor_150 = IF(Price_Change_150=0) THEN(0)
  ELSE(IF(Price_Change_150>0.5)THEN(1)ELSE(Price_Change_150*2))
○ Price_Factor_300 = IF(Price_Change_300=0) THEN(0)
  ELSE(IF(Price_Change_300>0.5)THEN(1)ELSE(Price_Change_300*2))
○ Price_Factor_600 = IF(Price_Change_600=0) THEN(0)
  ELSE(IF(Price_Change_600>0.5)THEN(1)ELSE(Price_Change_600*2))
○ Price_Factor_SO = IF(Price_Change_SO=0) THEN(0)
  ELSE(IF(Price_Change_SO>0.5)THEN(1)ELSE(Price_Change_SO*2))
○ SO_Rate =
  IF((Last_Month_Orders_SO*External_Factor*Unmet_Orders_Factor_SO*(1-Price_Factor_SO)*Take_Order_
  SO)>0)THEN(Last_Month_Orders_SO*External_Factor*Unmet_Orders_Factor_SO*(1-Price_Factor_SO)*Ta
  ke_Order_SO)ELSE(0)
○ Take_Order_150 = IF(TIME>3)AND(Number_of_Workers<=0)THEN(0)ELSE(1)
○ Take_Order_300 = IF(TIME>3)AND(Number_of_Workers<=0)THEN(0)ELSE(1)
○ Take_Order_600 = IF(TIME>3)AND(Number_of_Workers<=0)THEN(0)ELSE(1)
○ Take_Order_SO = IF(TIME>3)AND(Number_of_Workers<=0)THEN(0)ELSE(1)
○ Unmet_Orders_150 = IF(Unmet_Orders_Calculation_150)>0THEN (Unmet_Orders_Calculation_150) ELSE
  (Initial_Unmet_Orders_150)
○ Unmet_Orders_300 = IF(Unmet_Orders_Calculation_300)>0THEN (Unmet_Orders_Calculation_300) ELSE
  (Initial_Unmet_Orders_300)
○ Unmet_Orders_600 = IF(Unmet_Orders_Calculation_600)>0THEN (Unmet_Orders_Calculation_600) ELSE
  (Initial_Unmet_Orders_600)
○ Unmet_Orders_Calculation_150 = DELAY(Last_Month_Orders_150,1,0)-Shipping_150
○ Unmet_Orders_Calculation_300 = DELAY(Last_Month_Orders_300,1,0)-Shipping_300
○ Unmet_Orders_Calculation_600 = DELAY(Last_Month_Orders_600,1,0)-Shipping_600
○ Unmet_Orders_Calculation_SO = DELAY(Last_Month_Orders_SO,1,0)-Shipping_SO
○ Unmet_Orders_SO = IF(Unmet_Orders_Calculation_SO)>0THEN (Unmet_Orders_Calculation_SO) ELSE
  (Initial_Unmet_Orders_SO)
```

```
⊘ Unmet_Orders_Factor_150 = GRAPH(Unmet_Orders_150)
  (0.00, 1.01), (50.0, 0.9), (100, 0.5), (150, 0.3), (200, 0.2)
⊘ Unmet_Orders_Factor_300 = GRAPH(Unmet_Orders_300)
  (0.00, 1.01), (50.0, 0.9), (100, 0.5), (150, 0.3), (200, 0.2)
⊘ Unmet_Orders_Factor_600 = GRAPH(Unmet_Orders_600)
  (0.00, 1.01), (50.0, 0.9), (100, 0.5), (150, 0.3), (200, 0.2)
⊘ Unmet_Orders_Factor_SO = GRAPH(Unmet_Orders_SO)
  (0.00, 1.01), (50.0, 0.9), (100, 0.5), (150, 0.3), (200, 0.2)
```

Production Sector

```
○ Awaiting_Orders = Awaiting_Orders_150+Awaiting_Orders_300+Awaiting_Orders_600+Awaiting_SO
○ Cash_For_Inventory =
  Cash_For_Inventory_150+Cash_For_Inventory_300+Cash_For_Inventory_600+Cash_For_Inventory_SO
○ Productivity =
  IF((Awaiting_Orders/Number_of_Workers)>20)THEN(20)ELSE(Awaiting_Orders/Number_of_Workers)
```

Special Orders Production Sub-Sector

```
☐ Awaiting_SO(t) = Awaiting_SO(t - dt) + (New_SO - Completed_SO) * dt
  INIT Awaiting_SO = 10
   INFLOWS:
     ⇨ New_SO = IF(SO_Rate>0)THEN(SO_Rate)ELSE(0)
   OUTFLOWS:
     ⇨ Completed_SO = Shipping_SO
☐ Finished_Products_SO(t) = Finished_Products_SO(t - dt) + (Production_SO - Shipping_SO) * dt
  INIT Finished_Products_SO = 10
   INFLOWS:
     ⇨ Production_SO =
        IF(TIME<=1)THEN(Awaiting_SO)ELSE(IF(Awaiting_SO>0)AND(Workers_SO>0)THEN(Workers_SO*
        Productivity)ELSE(0))
   OUTFLOWS:
     ⇨ Shipping_SO = Finished_Products_SO
☐ Inventory_SO(t) = Inventory_SO(t - dt) + (Materials_arrival_SO + Extra_Inventory_SO - Production_SO -
  Scrap_SO) * dt
  INIT Inventory_SO = 90
   INFLOWS:
     ⇨ Materials_arrival_SO = CONVEYOR OUTFLOW
         TRANSIT TIME = Supplier_Delivery_Time_SO
     ⇨ Extra_Inventory_SO = IF(TIME=1)THEN(Extra_Inventory_Order_SO)ELSE(0)
   OUTFLOWS:
     ⇨ Production_SO =
        IF(TIME<=1)THEN(Awaiting_SO)ELSE(IF(Awaiting_SO>0)AND(Workers_SO>0)THEN(Workers_SO*
        Productivity)ELSE(0))
     ⇨ Scrap_SO = Finished_Products_SO*Scrap_Rate
```

```
▥ Waiting_for_Materials_SO(t) = Waiting_for_Materials_SO(t - dt) + (New_SO_to_Suppliers -
  Materials_arrival_SO) * dt
  INIT Waiting_for_Materials_SO = 0
   TRANSIT TIME = varies
   INFLOW LIMIT = INF
   CAPACITY = INF

   INFLOWS:
     ⇨ New_SO_to_Suppliers = Order_size_SO*Cash_Availability_Factor
   OUTFLOWS:
     ⇨ Materials_arrival_SO = CONVEYOR OUTFLOW
          TRANSIT TIME = Supplier_Delivery_Time_SO
○ Cash_For_Inventory_SO = Extra_Inventory_SO*Price_SO
○ Extra_Inventory_Order_SO = 0
○ Major_Supplier_Capacity_SO = 10
○ Order_size_SO = IF(SO_Rate<=Major_Supplier_Capacity_SO) THEN (SO_Rate) ELSE
  (Major_Supplier_Capacity_SO)
○ Percentage_SO = Awaiting_SO/Awaiting_Orders
○ Supplier_Delivery_Time_SO = 1
○ Workers_SO = Number_of_Workers*Percentage_SO
```

Not in a sector

Appendix # 7

	Price %	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Total
Sales	100%	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	100%	457,522	509,870	576,939	600,996	625,972	594,917	488,503	463,966	474,267	579,794	620,601	634,351	6,627,699
Income	100%	198,728	231,662	273,857	288,991	304,704	285,167	218,219	202,782	209,263	275,652	301,325	309,976	3,100,326

Sales	70%	459,375	559,193	631,038	661,728	694,770	733,374	768,061	798,163	743,281	710,266	704,473	702,845	8,166,566
Cost	70%	336,675	397,946	442,046	460,884	481,166	504,863	526,154	544,632	510,944	490,678	487,123	486,123	5,669,233
Income	70%	122,700	161,247	188,992	200,844	213,603	228,511	241,906	253,531	232,337	219,588	217,351	216,722	2,497,333
Sales	80%	525,000	635,310	719,942	749,811	766,419	792,260	823,795	853,988	876,076	795,515	772,917	772,985	9,084,017
Cost	80%	376,957	444,668	496,617	514,952	525,146	541,009	560,366	578,899	592,457	543,007	529,135	529,177	6,232,390
Income	80%	148,043	190,642	223,324	234,859	241,272	251,252	263,430	275,089	283,619	252,509	243,782	243,808	2,851,628
Sales	90%	590,625	700,700	805,450	840,049	853,196	862,703	873,470	883,960	893,014	906,087	924,694	945,174	10,079,123
Cost	90%	417,239	484,806	549,105	570,343	578,412	584,248	590,857	597,297	602,854	610,878	622,300	634,872	6,843,213
Income	90%	173,386	215,894	256,345	269,706	274,783	278,455	282,613	286,664	290,160	295,208	302,394	310,303	3,235,910
Sales	110%	721,875	738,709	673,894	513,870	413,733	288,285	180,947	146,367	135,540	162,267	173,672	120,945	4,270,104
Cost	110%	497,804	508,138	468,352	370,125	308,658	231,654	165,768	144,541	137,896	154,302	161,302	128,937	3,277,477
Income	110%	224,071	230,572	205,542	143,745	105,075	56,630	15,179	1,825	-2,356	7,966	12,370	-7,992	992,627
Sales	120%	787,500	729,414	499,011	232,235	94,453	39,239	29,694	36,877	34,294	27,950	19,028	7,821	2,537,517
Cost	120%	538,087	502,432	361,004	197,250	112,675	78,784	72,925	77,334	75,748	71,854	66,377	59,498	2,213,967
Income	120%	249,413	226,982	138,007	34,985	-18,223	-39,544	-43,230	-40,457	-41,454	-43,904	-47,349	-51,677	323,549
Sales	130%	853,125	715,115	340,387	107,701	34,077	10,964	4,976	5,140	4,710	3,477	1,764	558	2,081,994
Cost	130%	578,369	493,655	263,636	120,807	75,615	61,428	57,752	57,853	57,589	56,832	55,780	55,040	1,934,355
Income	130%	274,756	221,460	76,751	-13,106	-41,538	-50,463	-52,776	-52,713	-52,878	-53,355	-54,016	-54,482	147,639

Table 1 .- Price change simulation results (in CAD).

	Workers	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Total
Sales	6	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	6	457,522	509,870	576,939	600,996	625,972	594,917	488,503	463,966	474,267	579,794	620,601	634,351	6,627,699
Income	6	198,728	231,662	273,857	288,991	304,704	285,167	218,219	202,782	209,263	275,652	301,325	309,976	3,100,326

Sales	3	656,250	531,937	492,871	481,879	479,840	480,388	481,606	482,898	483,995	485,159	486,302	487,466	6,030,590
Cost	3	446,582	370,275	346,296	339,549	338,297	338,633	339,381	340,174	340,848	341,562	342,264	342,978	4,226,838
Income	3	209,668	161,661	146,575	142,331	141,543	141,755	142,225	142,724	143,148	143,597	144,039	144,488	1,803,752
Sales	4	656,250	640,035	634,991	634,634	635,770	637,357	639,014	640,260	640,997	641,510	642,050	643,246	7,686,113
Cost	4	450,229	440,276	437,179	436,960	437,658	438,632	439,649	440,414	440,866	441,181	441,513	442,246	5,286,802
Income	4	206,021	199,760	197,811	197,674	198,112	198,725	199,365	199,846	200,131	200,329	200,538	200,999	2,399,312
Sales	5	656,250	713,997	766,419	783,734	789,730	792,432	794,181	795,002	795,065	794,755	794,710	796,358	9,272,634
Cost	5	453,875	489,322	521,500	532,128	535,809	537,467	538,541	539,045	539,084	538,894	538,866	539,878	6,304,410
Income	5	202,375	224,675	244,919	251,605	253,921	254,964	255,640	255,957	255,981	255,862	255,844	256,481	2,968,224
Sales	7	656,250	741,532	860,928	887,755	964,198	860,820	677,998	652,851	684,291	917,645	1,050,390	1,090,651	10,045,308
Cost	7	461,168	513,517	586,805	603,272	650,196	586,739	474,518	459,082	478,381	621,620	703,102	727,816	6,866,214
Income	7	195,082	228,015	274,123	284,482	314,003	274,081	203,480	193,769	205,910	296,025	347,288	362,836	3,179,094
Sales	8	656,250	741,532	860,928	887,755	966,430	859,735	676,219	651,924	684,251	957,532	1,168,450	1,097,858	10,208,864
Cost	8	464,815	517,163	590,452	606,919	655,212	589,720	477,073	462,159	482,002	649,750	779,217	735,886	7,010,368
Income	8	191,435	224,369	270,476	280,836	311,218	270,016	199,147	189,765	202,248	307,782	389,233	361,972	3,198,497
Sales	9	656,250	741,532	860,928	887,755	966,430	859,735	676,219	651,924	684,251	961,814	1,218,665	1,070,467	10,235,971
Cost	9	468,461	520,810	594,098	610,565	658,858	593,366	480,719	465,806	485,649	656,025	813,687	722,719	7,070,765
Income	9	187,789	220,722	266,830	277,189	307,572	266,369	195,500	186,118	198,602	305,789	404,978	347,748	3,165,207

Table 2 .- Number of workers in the shop floor simulation table (in CAD).

	Max.Capacity	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Total
Sales	20 Pieces	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	20	457,522	509,870	576,939	600,996	625,972	594,917	488,503	463,966	474,267	579,794	620,601	634,351	6,627,699
Income	20	198,728	231,662	273,857	288,991	304,704	285,167	218,219	202,782	209,263	275,652	301,325	309,976	3,100,326

Sales	19	656,250	741,532	838,118	874,124	893,312	874,191	751,386	702,229	691,685	828,650	880,551	898,589	9,630,617
Cost	19	457,522	509,870	569,158	591,259	603,037	591,300	515,919	485,745	479,273	563,346	595,204	606,276	6,567,907
Income	19	198,728	231,662	268,961	282,865	290,275	282,891	235,467	216,484	212,412	265,304	285,347	292,313	3,062,709
Sales	18	656,250	729,811	814,648	841,916	850,862	854,247	817,612	765,389	709,501	804,056	839,987	853,187	9,537,464
Cost	18	457,522	502,675	554,751	571,488	576,980	579,058	556,570	524,514	490,209	548,249	570,305	578,407	6,510,728
Income	18	198,728	227,135	259,897	270,427	273,882	275,189	261,042	240,875	219,292	255,807	269,682	274,780	3,026,736
Sales	17	656,250	717,951	778,476	798,282	805,009	807,888	809,629	810,375	800,669	806,975	809,051	811,470	9,412,025
Cost	17	457,522	495,395	532,548	544,705	548,834	550,602	551,670	552,128	546,170	550,041	551,315	552,800	6,433,730
Income	17	198,728	222,555	245,929	253,577	256,175	257,287	257,959	258,247	254,499	256,934	257,736	258,670	2,978,295
Sales	16	656,250	701,698	740,915	754,190	759,033	761,476	763,245	764,192	764,390	764,151	764,101	765,552	8,959,193
Cost	16	457,522	485,419	509,491	517,640	520,613	522,113	523,198	523,780	523,901	523,754	523,724	524,614	6,155,769
Income	16	198,728	216,279	231,423	236,550	238,420	239,364	240,047	240,412	240,489	240,397	240,377	240,938	2,803,424
Sales	15	656,250	680,943	701,928	709,603	712,929	715,054	716,821	717,896	718,279	718,227	718,296	719,565	8,485,790
Cost	15	457,522	472,679	485,560	490,271	492,313	493,617	494,702	495,362	495,597	495,565	495,607	496,387	5,865,182
Income	15	198,728	208,264	216,368	219,332	220,616	221,437	222,119	222,534	222,682	222,662	222,689	223,179	2,620,609
Sales	14	656,250	660,188	662,939	664,965	666,740	668,490	670,192	671,360	671,940	672,223	672,580	673,797	8,011,663
Cost	14	457,522	459,939	461,628	462,871	463,961	465,035	466,080	466,797	467,152	467,326	467,546	468,292	5,574,149
Income	14	198,728	200,249	201,311	202,094	202,779	203,455	204,112	204,563	204,787	204,897	205,034	205,504	2,437,514

Table 3.- Productivity simulation table (in CAD).

	Sales%	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Total
Sales	100%	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	100%	457,522	509,870	576,939	600,996	625,972	594,917	488,503	463,966	474,267	579,794	620,601	634,351	6,627,699
Income	100%	198,728	231,662	273,857	288,991	304,704	285,167	218,219	202,782	209,263	275,652	301,325	309,976	3,100,326

Sales	70%	656,250	638,936	508,390	315,354	200,714	117,718	69,259	58,793	54,058	57,333	53,293	31,716	2,761,813
Cost	70%	457,522	446,894	366,761	248,271	177,901	126,956	97,210	90,786	87,880	89,890	87,410	74,165	2,351,647
Income	70%	198,728	192,042	141,629	67,084	22,813	-9,238	-27,952	-31,993	-33,822	-32,557	-34,117	-42,450	410,166
Sales	80%	656,250	671,554	612,631	467,154	376,121	262,077	164,497	133,061	123,218	147,516	157,884	109,950	3,881,913
Cost	80%	457,522	466,916	430,747	341,450	285,571	215,567	155,670	136,374	130,332	145,247	151,611	122,188	3,039,195
Income	80%	198,728	204,638	181,884	125,705	90,550	46,509	8,827	-3,313	-7,114	2,269	6,273	-12,238	842,718
Sales	90%	656,250	705,740	729,650	655,374	623,335	495,760	347,756	301,685	293,318	380,201	447,637	348,997	5,985,702
Cost	90%	457,522	487,900	502,577	456,984	437,318	359,009	268,159	239,880	234,744	288,075	329,469	268,921	4,330,558
Income	90%	198,728	217,840	227,073	198,390	186,017	136,751	79,596	61,805	58,574	92,126	118,167	80,075	1,655,143
Sales	110%	656,250	765,907	890,928	931,185	944,591	950,884	955,853	959,940	963,299	967,724	973,567	986,886	10,947,012
Cost	110%	457,522	524,832	601,574	626,284	634,513	638,376	641,426	643,935	645,997	648,713	652,300	660,475	7,375,947
Income	110%	198,728	241,075	289,354	304,901	310,078	312,508	314,427	316,005	317,302	319,011	321,267	326,411	3,571,065
Sales	120%	656,250	778,556	894,945	933,388	947,995	958,559	970,522	982,178	992,238	1,006,763	1,027,438	1,050,194	11,199,025
Cost	120%	457,522	532,596	604,039	627,637	636,603	643,087	650,431	657,585	663,760	672,676	685,367	699,335	7,530,640
Income	120%	198,728	245,959	290,906	305,751	311,392	315,472	320,091	324,593	328,477	334,087	342,071	350,858	3,668,386
Sales	130%	656,250	791,478	899,057	935,743	952,378	972,618	1,000,519	1,027,068	1,046,797	1,069,462	983,422	934,619	11,269,412
Cost	130%	457,522	540,528	606,564	629,082	639,293	651,717	668,844	685,140	697,251	711,163	658,349	628,392	7,573,845
Income	130%	198,728	250,949	292,494	306,661	313,085	320,901	331,676	341,928	349,547	358,299	325,073	306,227	3,695,567

Table 4 .- Sales variation simulation results (in CAD).

	Cost %	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Total
Sales	100%	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	100%	457,522	509,870	576,939	600,996	625,972	594,917	488,503	463,966	474,267	579,794	620,601	634,351	6,627,699
Income	100%	198,728	231,662	273,857	288,991	304,704	285,167	218,219	202,782	209,263	275,652	301,325	309,976	3,100,326

Sales	70%	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	70%	311,136	346,735	392,345	408,705	425,689	404,571	332,204	315,518	322,523	394,286	422,037	431,388	4,507,135
Income	70%	345,114	394,797	458,451	481,283	504,986	475,513	374,518	351,231	361,007	461,160	499,889	512,939	5,220,889
Sales	80%	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	80%	359,061	400,145	452,780	471,660	491,260	466,889	383,376	364,119	372,203	455,020	487,045	497,837	5,201,394
Income	80%	297,189	341,388	398,016	418,328	439,415	413,195	323,347	302,630	311,327	400,426	434,880	446,490	4,526,630
Sales	90%	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	90%	407,857	454,523	514,312	535,757	558,021	530,338	435,475	413,602	422,784	516,856	553,233	565,491	5,908,249
Income	90%	248,393	287,009	336,484	354,230	372,654	349,746	271,247	253,147	260,745	338,590	368,692	378,836	3,819,776
Sales	110%	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	110%	508,056	566,187	640,664	667,378	695,112	660,628	542,460	515,212	526,651	643,834	689,148	704,417	7,359,745
Income	110%	148,194	175,345	210,132	222,610	235,564	219,457	164,263	151,536	156,879	211,613	232,778	239,910	2,368,280
Sales	120%	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	120%	559,460	623,472	705,485	734,901	765,442	727,468	597,344	567,340	579,936	708,975	758,874	775,688	8,104,386
Income	120%	96,790	118,060	145,311	155,086	165,234	152,616	109,378	99,408	103,594	146,471	163,052	168,639	1,623,638
Sales	130%	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	130%	611,734	681,727	771,402	803,567	836,961	795,440	653,158	620,350	634,122	775,219	829,780	848,165	8,861,623
Income	130%	44,516	59,806	79,394	86,420	93,715	84,645	53,565	46,399	49,407	80,228	92,146	96,162	866,401

Table 5 .- Cost variation simulation results (in CAD).

	Ex.Rate%	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Total
Sales	100%	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	100%	457,522	509,870	576,939	600,996	625,972	594,917	488,503	463,966	474,267	579,794	620,601	634,351	6,627,699
Income	100%	198,728	231,662	273,857	288,991	304,704	285,167	218,219	202,782	209,263	275,652	301,325	309,976	3,100,326
Sales	70%	656,250	741,505	850,427	890,178	930,730	884,349	715,143	673,365	687,299	856,767	922,298	944,375	9,752,686
Cost	70%	457,522	509,854	576,713	601,114	626,005	597,535	493,672	468,027	476,580	580,605	620,829	634,381	6,642,837
Income	70%	198,728	231,651	273,714	289,065	304,725	286,814	221,471	205,337	210,718	276,162	301,469	309,994	3,109,849
Sales	80%	656,250	741,514	850,550	890,116	930,712	882,963	712,302	671,124	686,035	856,327	922,174	944,360	9,744,427
Cost	80%	457,522	509,859	576,789	601,075	625,994	596,684	491,928	466,652	475,804	580,335	620,754	634,371	6,637,767
Income	80%	198,728	231,655	273,762	289,041	304,718	286,279	220,374	204,472	210,230	275,992	301,421	309,988	3,106,660
Sales	90%	656,250	741,523	850,673	890,052	930,694	881,573	709,460	668,879	684,762	855,883	922,050	944,344	9,736,143
Cost	90%	457,522	509,865	576,864	601,036	625,983	595,831	490,183	465,274	475,024	580,062	620,677	634,362	6,632,682
Income	90%	198,728	231,658	273,809	289,016	304,711	285,742	219,276	203,605	209,739	275,821	301,373	309,982	3,103,461
Sales	110%	656,250	741,541	850,918	889,922	930,657	878,567	704,012	664,645	682,302	855,009	921,801	944,309	9,719,934
Cost	110%	457,522	509,876	577,015	600,956	625,960	593,986	486,839	462,675	473,513	579,525	620,524	634,341	6,622,733
Income	110%	198,728	231,665	273,904	288,966	304,697	284,581	217,173	201,970	208,789	275,483	301,277	309,969	3,097,201
Sales	120%	656,250	741,550	851,041	889,855	930,638	877,046	701,300	662,539	681,067	854,568	921,676	944,292	9,711,822
Cost	120%	457,522	509,882	577,090	600,915	625,949	593,052	485,175	461,382	472,755	579,255	620,447	634,330	6,617,754
Income	120%	198,728	231,669	273,951	288,940	304,689	283,993	216,125	201,157	208,312	275,313	301,228	309,962	3,094,069
Sales	130%	656,250	741,559	851,163	889,788	930,619	875,520	698,587	660,429	679,827	854,125	921,549	944,273	9,703,690
Cost	130%	457,522	509,887	577,165	600,874	625,937	592,116	483,509	460,087	471,994	578,983	620,370	634,319	6,612,762
Income	130%	198,728	231,672	273,998	288,914	304,682	283,404	215,078	200,342	207,833	275,142	301,180	309,955	3,090,928

Table 6 .- Exchange Rate variation simulation results (in CAD).

	Industry%	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Total
Sales	100%	656,250	741,532	850,796	889,987	930,676	880,084	706,723	666,748	683,529	855,446	921,926	944,327	9,728,024
Cost	100%	457,522	509,870	576,939	600,996	625,972	594,917	488,503	463,966	474,267	579,794	620,601	634,351	6,627,699
Income	100%	198,728	231,662	273,857	288,991	304,704	285,167	218,219	202,782	209,263	275,652	301,325	309,976	3,100,326
Sales	70%	656,250	684,034	654,614	532,038	457,574	335,153	217,905	179,821	169,387	210,083	234,391	170,611	4,501,861
Cost	70%	457,522	474,576	456,517	381,277	335,569	260,424	188,454	165,077	158,672	183,652	198,573	159,423	3,419,736
Income	70%	198,728	209,458	198,096	150,761	122,005	74,729	29,451	14,745	10,715	26,431	35,818	11,188	1,082,125
Sales	80%	656,250	702,725	719,144	637,337	598,085	470,139	325,709	280,505	271,697	350,813	410,924	317,455	5,740,784
Cost	80%	457,522	486,050	496,128	445,913	421,818	343,282	254,627	226,879	221,473	270,036	306,934	249,560	4,180,221
Income	80%	198,728	216,676	223,016	191,425	176,266	126,857	71,082	53,626	50,224	80,777	103,990	67,895	1,560,563
Sales	90%	656,250	721,890	787,840	755,359	765,938	642,038	474,449	431,285	433,394	582,873	714,482	583,035	7,548,832
Cost	90%	457,522	497,813	538,296	518,358	524,851	448,798	345,927	319,432	320,727	412,481	493,266	412,580	5,290,051
Income	90%	198,728	224,076	249,545	237,001	241,087	193,240	128,522	111,853	112,667	170,392	221,216	170,455	2,258,781
Sales	110%	656,250	760,226	889,131	930,311	943,692	949,063	952,459	954,378	955,181	956,086	957,963	964,388	10,869,129
Cost	110%	457,522	521,345	600,470	625,748	633,961	637,259	639,343	640,521	641,014	641,569	642,722	646,666	7,328,140
Income	110%	198,728	238,881	288,660	304,563	309,730	311,805	313,116	313,857	314,167	314,517	315,242	317,723	3,540,989
Sales	120%	656,250	767,003	891,275	931,366	944,845	951,363	956,648	961,180	965,049	970,162	976,866	991,316	10,963,323
Cost	120%	457,522	525,505	601,787	626,396	634,670	638,670	641,914	644,696	647,071	650,210	654,324	663,195	7,385,959
Income	120%	198,728	241,498	289,488	304,971	310,176	312,693	314,734	316,484	317,978	319,952	322,541	328,122	3,577,364
Sales	130%	656,250	773,861	893,451	932,549	946,621	955,227	963,448	971,147	978,143	987,713	1,001,888	1,022,200	11,082,500
Cost	130%	457,522	529,714	603,122	627,122	635,760	641,042	646,088	650,814	655,109	660,983	669,684	682,152	7,459,113
Income	130%	198,728	244,146	290,329	305,427	310,862	314,185	317,360	320,333	323,035	326,730	332,204	340,048	3,623,387

Table 7 .- Industry factor variation simulation results (in CAD).